3

SURVEY REPORT + 3a

(APPENDICES)

3a

# BRAZOS RIVER WATERSHED

## TEXAS

PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION



U. S. DEPARTMENT OF AGRICULTURE

January 1951

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# BRAZOS RIVER WATERSHED

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# APPENDIX I

## PHYSICAL FACTORS

### DESCRIPTION OF THE AREA

The Brazos River Watershed in Texas extends from eastern New Mexico, near Clovis, in a southeasterly direction diagonally across the State of Texas to the Gulf of Mexico. The watershed has an overall length of 640 miles and a maximum width of about 120 miles. The total area is 44,670 square miles, of which 41,997 square miles are in Texas.

The principal tributaries entering the Brazos below its source at the junction of the Double Mountain Fork and Salt Fork are the Clear Fork, Bosque River, Little River, Yegua Creek and the Navasota River. All tributary drainage systems except the two first named are dentritic rather than long and narrow. This characteristic tends to produce synchronization of flood flows and consequent concentration of flood waters on the main streams of the tributaries.

In general the watershed consists of a series of plains stepped down from the 4,500 foot elevation of the western High Plains plateau to sea level at the mouth. These plains occur as belts across the watershed and contribute to the separation of the watershed into smaller units for survey purposes.

### CONSERVATION PROBLEM AREAS

The watershed was divided into 11 conservation problem areas to facilitate hydrologic and economic investigation (figure 1). Each conservation problem area is an association of soil, slope, erosion and other conditions which is characterized by essentially uniform rates of runoff, sedimentation, and deterioration of soil resources under similar cover and treatment. Each conservation problem area is readily recognizable. In the field the names of each are used locally by technicians in agricultural work. A brief description of these areas follows:

<u>High Plains</u>: This is a prairie plateau at the extreme northwestern end of the watershed which occupies nearly 17 percent of the watershed area (table 1). About 2,673 square miles is in New Mexico and 8,950 square miles does not contribute directly to flood flow. The surface is usually smooth and level, and stream dissection is slight. The major waterways occupy shallow, smooth-sloped drainage trenches and are dry most of the year. Most of the rainfall which does not sink into the soil where it falls drains into the shallow basins or depression ponds which dot the surface of the plateau. On

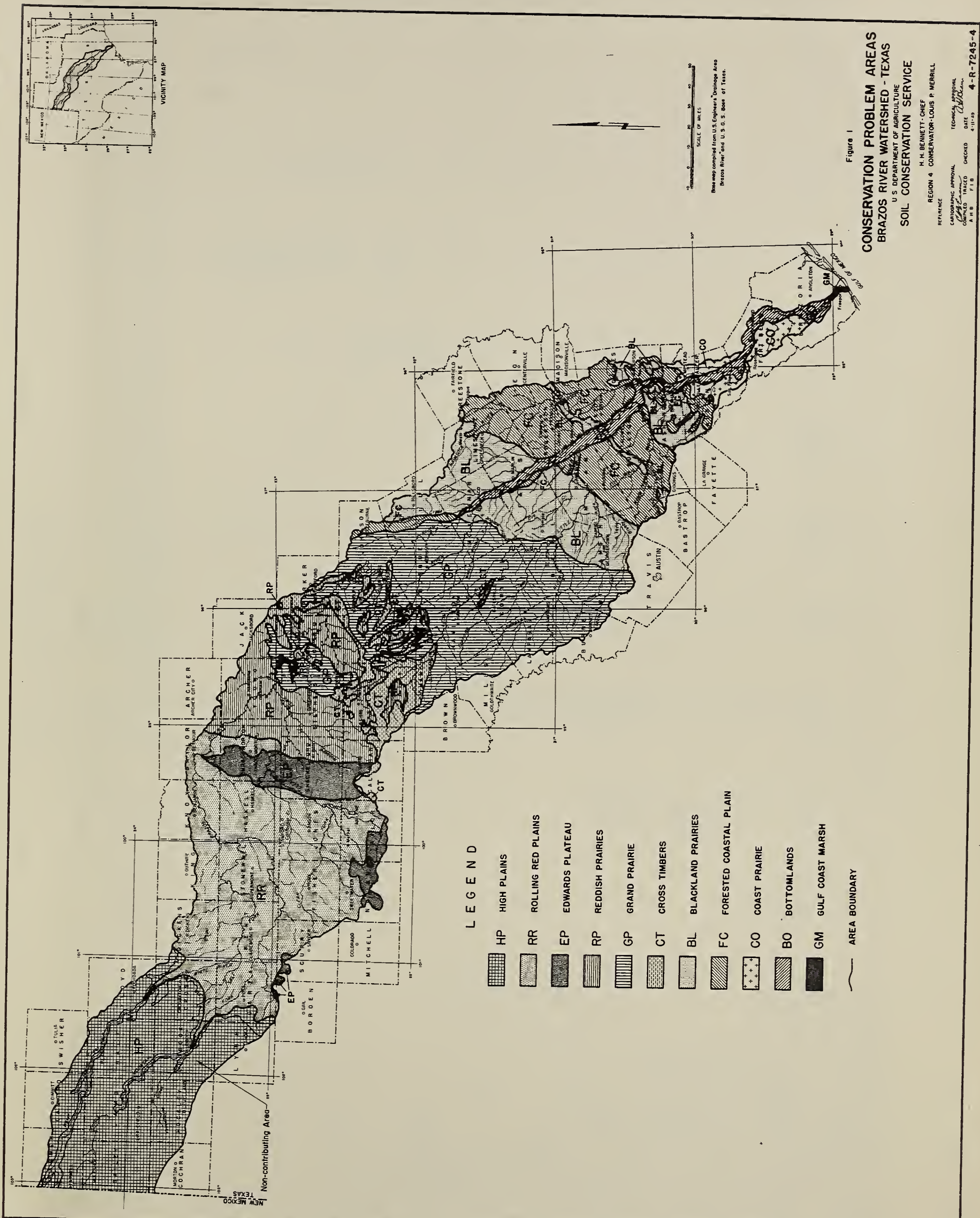
Figure I
CONSERVATION PROBLEM AREAS
BRAZOS RIVER WATERSHED - TEXAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P. MERRILL
4-R-7245-4
VICINITY MAP
SCALE OF MILES
Base map compiled from U.S. Engineers "Drainage Area Brazos River" and U.S.G.S. Base of Texas.
LEGEND
HP HIGH PLAINS
RR ROLLING RED PLAINS
EP EDWARDS PLATEAU
RP REDDISH PRAIRIES
GP GRAND PRAIRIE
CT CROSS TIMBERS
BL BLACKLAND PRAIRIES
FC FORESTED COASTAL PLAIN
CO COAST PRAIRIE
BO BOTTOMLANDS
GM GULF COAST MARSH
AREA BOUNDARY
Non-contributing Area
NEW MEXICO
TEXAS
GULF OF MEXICO

Table 1. Area of Conservation Problem Areas by Subwatersheds
Brazos River Watershed

| Subwatershed | Bottom-land | Coast Prairie | Forested Coastal Plain | Black-land Prairie | East Cross Timbers | Grand Prairie | Cross Timbers | Reddish Prairie | Rolling Red Plains | Edwards Plateau | High Plains | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) | (sq.mi.) |
| Non-contributing | - | - | - | - | - | - | - | - | - | - | 6,419 | 6,419 |
| White River | - | - | - | - | - | - | - | - | 247 | - | 296 | 543 |
| Salt Fork | - | - | - | - | - | - | - | - | 1,903 | - | 32 | 1,935 |
| Double Mountain Fork | - | - | - | - | - | - | - | - | 1,946 | 19 | 168 | 2,133 |
| Brazos above P.K. 1/ | - | - | - | - | - | - | - | 746 | 1,455 | 327 | - | 2,528 |
| Elm Creek | - | - | - | - | - | - | - | - | 344 | 145 | - | 489 |
| California Creek | - | - | - | - | - | - | - | - | 952 | 112 | - | 1,064 |
| Hubbard Creek | - | - | - | - | - | - | - | 1,093 | - | 181 | - | 1,274 |
| Clear Fork | - | - | - | - | - | - | - | 387 | 1,675 | 843 | - | 2,905 |
| Possum Kingdom | - | - | - | - | - | 379 | 21 | 685 | - | - | - | 1,085 |
| Palo Pinto Creek | - | - | - | - | - | 170 | 89 | 369 | - | - | - | 628 |
| Paluxy Creek | - | - | - | - | - | 327 | 105 | - | - | - | - | 432 |
| P.K. to Whitney 1/ | 152 | - | - | - | - | 1,134 | 583 | 299 | - | - | - | 2,168 |
| Nolands River | - | - | - | - | 70 | 260 | - | - | - | - | - | 330 |
| Aquilla Creek | - | - | - | 261 | 156 | - | - | - | - | - | - | 417 |
| Whitney to Waco | 15 | - | - | 17 | 46 | 202 | - | - | - | - | - | 280 |
| Bosque River | - | - | - | 96 | - | 1,346 | 234 | - | - | - | - | 1,676 |
| Waco to Little River | 159 | - | 55 | 1,233 | 48 | - | - | - | - | - | - | 1,495 |
| Little River 2/ | - | - | 229 | 1,563 | - | 4,282 | 1,006 | 293 | - | - | - | 7,373 |
| Little Brazos | 65 | - | 448 | 145 | - | - | - | - | - | - | - | 658 |
| Navasota R. below dam | - | - | 324 | 71 | - | - | - | - | - | - | - | 395 |
| Navasota R. above dam | - | - | 1,309 | 473 | - | - | - | - | - | - | - | 1,782 |
| Yegua Creek below dam | - | - | 267 | 52 | - | - | - | - | - | - | - | 319 |
| Yegua Creek above dam | - | - | 870 | 142 | - | - | - | - | - | - | - | 1,012 |
| Mill Creek | - | 93 | 90 | 215 | - | - | - | - | - | - | - | 398 |
| Little R. to Irrigation | 366 | 399 | 516 | 353 | - | - | - | - | - | - | - | 1,634 |
| Irrigation to Mouth | 327 | 298 | - | - | - | - | - | - | - | - | - | 625 |
| Total | 1,084 | 790 | 4,108 | 4,621 | 320 | 8,100 | 2,038 | 3,872 | 8,522 | 1,627 | 6,915 | 41,997 |
| Percent of Total | 2.6 | 1.9 | 9.8 | 11.0 | 0.8 | 19.2 | 4.9 | 9.2 | 20.2 | 3.9 | 16.5 | 100 |

1/ P.K. is Possum Kingdom

2/ Little River Survey Report uses 7,545 square miles as total area; 7,373 agrees with U.S.E.D. area.

the east, the plateau is bordered by a rough and well-defined escarpment reaching down to the Rolling Red Plains.

The soils are deeply developed and have relatively rapid infiltration rates. The northern portions of the plateau are occupied by dark, heavy soils, while the southern and central portions are of lighter textured, sandy reddish soils which are subject to wind erosion. Most of the escarpment and sandy areas are retained in native grasses for pasture, while the remaining area is cropped. The installation of irrigation facilities is rapidly increasing whenever shallow water supplies are available and the remaining area is dry farmed. The major crops are wheat, cotton, and grain sorghums. Lubbock, with a population of 32,000, is the largest town.

Flood damages within the area are negligible and usually caused by excessive rainfall over small areas rather than by the concentration of runoff waters in rivers.

Rolling Red Plains: Below the High Plains "Cap Rock" is a rolling, rough, mixed ranch and farm area. This plain extends to the Edwards Plateau outlier south of Seymour and occupies 20 percent of the Brazos River Watershed in Texas. Although the Salt Fork and the Double Mountain Fork of the Brazos have their upper watersheds in the High Plains, nearly all of the runoff waters in these two rivers are from the Rolling Plains. These two forks join to form the Brazos River near the center of the Rolling Red Plains area. The Clear Fork of the Brazos drains the southern portion of the area.

The area is a broad plain of sandstone and shale outcrop in a sub-humid climate. Soils are predominantly red in color and are underlain by beds of caliche (carbonate accumulation). The soils are moderately fine textured at the surface and are best suited to small grains and grain sorghums. Fields are subject to severe wind and water erosion under the usual dry farming methods employed.

The rougher breaks, escarpment areas, and sand hills are covered with a moderately vigorous growth of short and mid-grasses and are heavily invaded by mesquite. Excessive use of the range grasses and deterioration of the cover is typical of a high percentage of the area.

Streams are narrow and rapidly eroding at the heads and are incising their channels to their junctions with the main streams. The main streams have wide alluvial valleys with trenched and meandering dry stream channels which are choked with sand. Often sand dunes paralleling the channel characterize the valley. The sides of the valley in most places are rough and broken cliffs or escarpments of Redbeds which are undercut by meanders of the channel. Only a small percentage of the valley is covered by the usual

high water during seasonal rains and much of the valley is above the level of known floods.

About 38 percent of the land is used primarily as range for cattle and sheep (Rangeland, table 2). This area is not much rougher than the cultivated area but is either in large ranch holdings or is dissected by the numerous dry streams. Another 10 percent of the Rolling Plains area is intermingled with this range country and is known as "breaks" or "bad lands". These are rough, gullied, deeply dissected strips along streams, the watersheds of small tributaries or escarpment areas which are used for grazing. The very sparse cover of grasses and weeds, with some mesquite and juniper, appears unsuited to any grazing but lightly-stocked areas produce some income. Erosion is very rapid and runoff from the hard-baked surface soil is excessive.

About one-fourth of the area is predominantly arable rolling farmland with moderately deep red clay loam or sandy loam soils while one-fifth is occupied by dark smooth deeply developed soils used for cultivation. Slopes are usually gentle but often approach the limits of safe cultivation in the sandy soils and a rather high percentage should be retired from crop production.

The remaining eight percent is called "shinnery" or "shinnery sand". These long narrow belts of unconsolidated and loose sandy soils parallel the rivers and are usually used for pasture except near the transition into heavier soils where cultivation is profitable. A sparse cover of tall native grasses and a heavy cover of shin-oak brush furnishes forage for beef cattle during part of the year. These sand hills produce no appreciable runoff during flood producing storms but are susceptible to severe damage from blowing when cropped or overgrazed.

Abilene (population 27,000) and Sweetwater (population 10,000) are the large towns in this area.

Edwards Plateau: This narrow outlier cuts across the watershed from Abilene to Seymour and both the Clear Fork and the Brazos River have incised deep valleys through it. Typically the plateau is bordered by a rough escarpment reaching down to the Rolling Plains to the north and west and to the Reddish Prairie on the east. The edge of the main Edwards Plateau lies at the south watershed boundary to the west of Abilene with some outliers or tongues from the plateau reaching into the watershed.

The area occupies less than four percent of the watershed and is a smoothly rolling mesquite savannah similar to the Grand Prairie. Soils are shallow over limestone parent materials but absorb rainfall rapidly and support a good cover of short and mid-grasses and mesquite

Table 2. Area and Percent of Subproblem Areas 1/ Within Conservation Problem Areas by Subwatersheds

Brazos River Watershed

| Conservation Problem Areas and Subwatersheds | Farmland (Predominantly: Crop and General Farm) | | Rangeland (Predominantly Ranches) | | Shinnery 3/ (Predominantly Grazing Areas) | | Rough and Broken (Predominantly Ranches) | | Dark and Smooth (Predominantly Crop Farms) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (sq.mi.) | (percent) | (sq.mi.) | (percent) | (sq.mi.) | (percent) | (sq.mi.) | (percent) | (sq.mi.) | (percent) |
| **Rolling Red Plains Subwatershed** | | | | | | | | | | |
| White River | 11 | 4 | 194 | 80 | 39 | 16 | - | - | - | - |
| Salt Fork | 232 | 12 | 845 | 46 | 333 | 18 | 244 | 13 | 203 | 11 |
| Double Mountain Fork | 251 | 13 | 1,085 | 57 | 72 | 4 | 292 | 15 | 209 | 11 |
| Elm Creek | 200 | 60 | 87 | 26 | - | - | - | - | 49 | 14 |
| California Creek | 303 | 32 | 172 | 18 | 14 | 1 | 23 | 2 | 440 | 47 |
| Brazos above Possum Kingdom | 389 | 28 | 422 | 30 | 63 | 5 | 96 | 7 | 412 | 30 |
| Clear Fork | 735 | 44 | 368 | 22 | 122 | 7 | 75 | 5 | 375 | 22 |
| Totals | 2,121 | 25 | 3,173 | 38 | 643 | 8 | 730 | 9 | 1,688 | 20 |

| | Farmland (Predominantly Crop and General Farms) | | Mesquite Rangeland 4/ (Predominantly Ranches) | | Oak & Cedar Rangeland 5/ (Predominantly Ranches and Livestock Farms) | |
|---|---|---|---|---|---|---|
| | (sq.mi.) | (percent) | (sq.mi.) | (percent) | (sq.mi.) | (percent) |
| **Reddish Prairie Subwatershed** | | | | | | |
| Little River | - | - | - | - | 293 | 100 |
| Hubbard Creek | 140 | 13 | 716 | 68 | 194 | 19 |
| Brazos above Possum Kingdom | 392 | 53 | 282 | 38 | 72 | 9 |
| Clear Fork | 33 | 11 | 224 | 80 | 25 | 9 |
| Possum Kingdom | 233 | 35 | 263 | 40 | 169 | 25 |
| Palo Pinto Creek | 111 | 30 | - | - | 258 | 70 |
| Possum Kingdom to Whitney | 129 | 43 | - | - | 170 | 57 |
| Totals | 1,038 | 28 | 1,485 | 40 | 1,181 | 32 |

1/ Subproblem Area names do not refer to actual land use but are descriptive terms used for identification.
3/ Grassland which has been invaded by Shin-Oak shrubs.
4/ Grassland which has been invaded by Mesquite trees and associated shrubs.
5/ Grassland with rough topography which has been invaded by Cedar, Oak and associated trees and shrubs.

Table 2. (continued) Area and Percent of Subproblem Areas 1/ within Conservation Problem Areas by Subwatersheds

Brazos River Watershed

| Conservation Problem Areas and Subwatersheds | Farmland (Predominantly General Farms) | | Woodland 3/ (Predominantly Ranches and Livestock Farms) | |
|---|---|---|---|---|
| | (sq. mi.) | (percent) | (sq. mi.) | (percent) |
| West Cross Timbers | | | | |
| Subwatershed | | | | |
| Possum Kingdom to Whitney | 525 | 90 | 58 | 10 |
| Paluxy Creek | 75 | 72 | 30 | 28 |
| Palo Pinto Creek | 59 | 66 | 30 | 34 |
| Possum Kingdom | 21 | 100 | - | - |
| Clear Fork | 8 | 100 | - | - |
| Hubbard Creek | 43 | 100 | - | - |
| Little River | 1,006 | 100 | - | - |
| Bosque River | 234 | 100 | - | - |
| Totals | 1,971 | 94 | 118 | 6 |

| Conservation Problem Areas and Subwatersheds | Farmland (Predominantly General Farms) | | Woodland (Predominantly Ranches and Livestock Farms) | | Rangeland (Predominantly Ranches) | |
|---|---|---|---|---|---|---|
| | (sq.mi.) | (percent) | (sq.mi.) | (percent) | (sq.mi.) | (percent) |
| Grand Prairie | | | | | | |
| Subwatershed | | | | | | |
| Whitney to Waco | 100 | 50 | 20 | 10 | 82 | 40 |
| Nolands River | 171 | 66 | 10 | 4 | 79 | 30 |
| Possum Kingdom to Whitney | 111 | 10 | 368 | 32 | 655 | 58 |
| Paluxy Creek | - | - | 240 | 73 | 87 | 27 |
| Palo Pinto Creek | - | - | 125 | 74 | 45 | 26 |
| Possum Kingdom | - | - | 166 | 47 | 186 | 53 |
| Bosque River | 697 | 52 | 278 | 20 | 371 | 28 |
| Totals | 1,079 | 28 | 1,207 | 32 | 1,505 | 40 |

1/ Subproblem Area names do not refer to actual land use but are descriptive terms used for identification.
3/ Post-Oak and Blackjack Oak Savannah.
4/ Grassland which has been invaded by Liveoak, Cedar and associated trees and shrubs.

Table 2. (continued) Area and Percent of Subproblem Areas 1/ within Conservation Problem Areas by Subwatersheds

Brazos River Watershed

| Conservation Problem Areas and Subwatersheds | Farmland (Predominantly General and Livestock Farms) | | Woodland 2/ (Predominantly Livestock Farms and Ranches) | |
|---|---|---|---|---|
| | (sq. mi.) | (percent) | (sq. mi.) | (percent) |
| Forested Coastal Plain | | | | |
| Subwatershed | | | | |
| Little River to Irrigation | 257 | 50 | 259 | 50 |
| Mill Creek | 27 | 30 | 63 | 70 |
| Yegua above dam | 347 | 41 | 495 | 59 |
| Yegua below dam | 77 | 33 | 159 | 67 |
| Navasota above dam | 665 | 55 | 550 | 45 |
| Navasota below dam | 70 | 24 | 215 | 76 |
| Little Brazos River | 295 | 66 | 153 | 34 |
| Waco to Little River | 29 | 53 | 26 | 47 |
| Little River | 229 | 100 | - | - |
| Totals | 1,996 | 51 | 1,920 | 49 |

1/ Subproblem area names do not refer to actual land use but are descriptive terms used for identification.

2/ Post-Oak Savannah.

trees. Dissection is well advanced but the underlying rocks limit the speed of stream cutting. Very little of the plateau lying in the Brazos River Watershed is cultivated and the present rate of soil losses is very small although spectacular ravines and stream channel cutting are apparent.

Reddish Prairie: The Reddish Prairie occupies about nine percent of the watershed area in the central section. It is underlain by limestones, sandstones and shales of Pennsylvanian Age. Exposure of these rocks has resulted in a series of discontinuous ridges, valleys, mesas, hills and rough areas. The topography is mostly unsuited to crop production and the soils developed are somewhat lacking in fertility. A rather sparse cover of mid- and tall-grasses with a heavy growth of oak and juniper is characteristic of the steep slopes while the smoother shale valleys are occupied by short grasses and mesquite brush. Some large areas near the divide on the northern edges of the watershed are occupied by dark, heavy, intractable clays suited to wheat and cotton production.

Since the soils are not highly productive most of the area is used for grazing of cattle, sheep and goats. The rough ridges covered with cedar and oak occupy about 48 percent of the area (table 2) while the mesquite pastures include about 24 percent. Land suited to crop production as well as grazing occupies about 28 percent of the Reddish Prairie. Oil production, use of local clays for ceramic products, coal and other mineral exploitation occupy an important place in the economy of this conservation problem area.

Cross Timbers: The Cross Timbers is a wooded belt extending from north to south across the watershed. It lies between the Reddish Prairie to the west and the Grand Prairie on the east. This wooded area occupies nearly 5 percent of the watershed. Loose incoherent sands and deep sandy topsoils predominate. Nearly all soils are underlain by heavy sandy clay subsoils which are relatively infertile and intractable.

Under past cultivation practices the loose soil has been subjected to severe erosion by wind and water action and many areas are encountered which are damaged beyond productive use for crops. Although rainfall enters the soil rapidly and is stored for later use, or transmitted to underground channels readily, the loose soil particles are easily detached and washed or blown away.

A high proportion of the area has been cultivated at one time and is now abandoned to pasture use because of erosion damage and infertility. The scrubby woodland is not well suited to timber production and its chief use is for grazing and for fire or post-wood. Locally the trees are considered a weed vegetation.

The Cross Timbers are a major sediment producing area in the Brazos River Watershed. The alluvial valleys have several feet of sandy deposits on a large percentage of their surface and cultivation of the once-productive bottomlands has practically ceased. The sediment, usually of coarse sand, causes increasing and permanent damage to the fields and pastures while stream channels are choked by deposition. This impairs the surface drainage of the valley fields and increases the frequency of flooding in certain areas.

Grand Prairie: This area occupies 19 percent of the watershed and lies generally in the reach between Glen Rose and Waco. It is a dissected limestone plateau of smooth but rolling topography. While the greater portion is composed of areas with a shallow soil mantle most valleys and smooth ridges have some deeply developed soils suitable for sustained crop production. Soils are black to brown or gray in color and are usually a tight calcareous clay. The clay surface and subsoil inhibits the free movement of rainfall into the soil but once through the surface the broken and channeled character of the parent rock gives free movement to underground water. Seeps and springs, often seasonal, are common.

A high percentage of the land is used for ranching or the grazing of cattle, sheep and goats and the remnants of the original mid- and tall-grass vegetation furnish a partial cover for the rolling slopes of shallow soils. The shallow uplands, not well suited to crops, have forced the use of the bottomlands for forage crops. Since there is little damage from sediment in the flood plains and the channels are large enough to carry normal freshets, the bottomlands are used to produce the supplementary feed necessary for livestock production.

Tributaries have high discharge rates as shown by the vertical bluffs, uneven and rough bottomland areas, and the deep, steep-sided incised channels with numerous ledges, gravel bars, and pools.

There are three general subdivisions within the Grand Prairie based on differences in topography and soil development (table 2). These differences are reflected in the type of agriculture encountered and are important as they indicate the intensity of remedial treatment necessary.

Cultivated area: This division is characterized by smooth topography and a high percentage of arable soil. It occupies about 28 percent of the Grand Prairie. Between one-half and three-fourths of the division is suitable for crop production while the remainder is usually of shallow soils and is used for pasture. Soil and water losses from the cultivated fields are high due to the heavy clay soil and well-established surface drainage. In productivity, use and infiltration rates this area is similar to the Blackland Prairie.

Rangeland area: This division is characterized by smoothly rolling, shallow soils with a diminishing native cover of tall grasses and associated short grasses. The less valuable short grasses are increasing in relative density. Typically this has a savannah-like cover with knolls, valley sides and some rocky outcrops covered with live oak, sumac and some cedar while the remaining area is grass prairie spotted with clumps of mesquite. The rangeland occupies about 40 percent of the Grand Prairie and is primarily in large ranches or in livestock farms. Numerous areas on the smooth divides have developed sufficient soil depth to support crop farming and many of these areas have been plowed recently for wheat or for supplementary feed crops.

Woodland or brushy area: This division occupies about thirty-two percent of the Grand Prairie. It is predominantly an area of steep and abrupt slopes and valleys in which the soils are very shallow or are replaced by outcrops of rock. Nearly all of the area is covered with a thick and brushy growth of mesquite, red oak, live oak or cedar. Nearly all favorable areas in valleys or on divides are cultivated and in the past few years a high percentage of the open pasture has been cleared of brush and trees to improve the grass production. It is doubtful that there should be any considerable increase in cultivation or the rate of brush clearing in the future. Ranches and livestock farms are the typical farm types of the division.

Blackland Prairie: This intensively cultivated prairie occupies about 11 percent of the watershed. It was originally a smooth rolling "bluestem" prairie, used for grazing. The deep, fertile, black clay soil now supports an intensive type of cash crop farming with about 80 percent of the entire area under cultivation. The pasture and woodland is mainly located on the small bottomland areas or on steep slopes and abandoned fields. Vegetation in the upland pastures has changed to a short grass cover. In the few remaining upland meadows the original bluestem vegetation is cut for hay.

In the western edge of the area from Georgetown to Hillsboro, adjoining the Grand Prairie, the underlying rocks are white, chalky limestones. Here the soils are more shallow, more granular and pervious, and less fertile than in the central portion where the underlying materials are clays and marls. The eastern edge, from Cameron to Groesbeck is occupied by transition soils. These areas are sandy at the surface, intractable and not highly calcareous. Locally known as "hard lands" these sandy soils lack the granular structure of the black clays and are less fertile. Runoff and soil losses are high in all areas.

Extensive outcrops of calcareous materials in the Forested Coastal Plains near Brenham and Caldwell have resulted in rather

large discontinuous areas of Blackland Prairie which are not connected with the main body which lies between Waco and Marlin. In these areas the calcareous black clay surface soils are much the same as in the main body except that slopes are somewhat steeper, dissection more pronounced and there are higher percentages used for native meadow and woodland.

The Blackland Prairie is a critical contributor to floodwaters and to sediment accumulation. It ranks highest in the watershed in rate of runoff and amount of sediment washed from fields per unit area. The sediment from the black clay fields does not cause severe permanent damage when deposited on bottomland fields as its inherent fertility is high and the recovery of agricultural productive value is rapid.

About 4 percent of the area is characterized by steep slopes and escarpments usually along streams, 16 percent is occupied by the transition "hard lands" and the remainder is smoothly rolling. Waco (population 55,000) and Temple (population 15,000) are the large cities in the area.

Forested Coastal Plain: This conservation problem area occupies approximately 10 percent of the watershed, in the section between Marlin and Bellville. This is a rolling, sandy plain, originally forested in post-oak and associated tree and shrub species. Early settlement and cultivation in the area, coupled with the easily eroded and rapidly leached soils, has resulted in abandonment of a high percentage of the land to grazing use.

Stream channels in general are choked with sand from the upland fields and gullied areas. The alluvial areas are broad and flat and subject to numerous overflows which are usually long-continued because of the restricted drainage. The bottomland areas are not extensively cultivated as the water table is often high, the land swampy and only moderately fertile, and the vegetation exceptionally thick and heavy.

Since the low yields of crops in the uplands has discouraged cultivation there is a trend toward increasing the size of holdings and a change toward livestock farming. At least half of the area is predominately woodland which is used for grazing with only small patches of cultivated land (table 2), while in the remaining portion the openland and woodland are about equal in area.

A narrow band of this same unit occupies a strip between Cleburne and Waco. This area is very similar to the typical Forested Coastal Plain and is known locally as the East Cross Timbers. Agricultural use and practices are about the same in both areas. As

this band is narrow and parallels Aquilla Creek and Nolands River there is little development of flood plain. Sediment from this area, however, has some effect on the black clay flood plain lands in these streams.

Coast Prairie: This is a flat treeless area on the coast of the Gulf of Mexico. It occupies less than 2 percent of the watershed. There is included a small area of salt-water marsh near the mouth of the Brazos River at Freeport. The heavy dark clay and sandy loam soils are used in conjunction with the Brazos bottomlands and are extensively irrigated for rice production. The ramaining area is used as pasture for cattle. These areas contribute little to runoff and are not severely harmed by erosion. Typically they are slowly drained and flood plains within the Coast Prairie are minor in extent.

Bottomland: This refers to the main alluvial areas of the Brazos River which occupy more than 2 percent of the watershed. These alluvial soils are composed of sediments transported by the large tributaries which have carried material from all parts of the watershed toward the mouth of the Brazos River. The broad alluvial plain of the Brazos is not typical of the adjoining conservation problem areas and is considered separately.

The soils are reddish to gray or black in color, are fertile, easily worked, and permeable. The area is intensively cultivated and of high productivity. The river is deeply entrenched and is eroding its banks throughout the area from Waco to Freeport. There is considerable damage to bottomland farms caused by impeded drainage and lack of outlets for hill water into the main river channel. It is within this area that the program of the Department of the Army, Corps of Engineers, has its greatest effect.

## GEOLOGY AND PHYSIOGRAPHY

The size and length of the Brazos River Watershed are so great that most of the physiographic provinces and sub-provinces and systems of rock formation of Texas are contained within its drainage. The watershed drains parts of three large provinces, the Great Plains, the Central Lowlands and the West Gulf Coastal Plain. Topography ranges from high, flat youthful uplands through well-drained, mature and in places mountainous, sections to low, flat coastal plain. In general the belts of outcrop of the various rock formations extend transversely across the main drainage lines. Formations ranging in age from Pennsylvanian to Recent are represented. Because of its size and complexity, only broad generalizations of the effects of its various topographies, rock structure and lithology on the flood control problem are presented.

Great Plains Province

High Plains: The High Plains Section covers all or parts of 13 counties (figure 2). It is a nearly flat upland plain lying at elevations ranging from 4500 feet in the western part to approximately 3000 feet east of Lubbock. Local relief rarely exceeds 20 feet within one mile except in the immediate vicinity of the major valleys such as White River and Double Mountain Fork. The smooth surface of the plain is featured by hundreds of small, shallow intermittent lakes. Most of the area has virtually no surface drainage, hence rainfall which is not evaporated or stored seeps directly into underlying formations and does not contribute directly to stream runoff.

The High Plains were formed during Pliocene time by many relatively large streams which developed a great alluvial plain, the Ogallala formation, eastward from the Rocky Mountains (figure 2). It consists of irregularly stratified, chiefly unconsolidated material ranging from clay and silt to coarse gravel. Its thickness ranges from 100 feet or less to approximately 500 feet. In places it has zones of very strongly cemented sandstone and contains lens-shaped deposits of loose sands and gravels; consequently it has a relatively high porosity and permeability and forms a valuable groundwater producer and many springs issue from the formation at its eastern edge. At its base in most places occurs a well-cemented zone which is resistant to erosion and in places forms a part of the familiarly known "cap-rock" of the area. Its eastern fringe forms a prominent escarpment which is deeply, and in places spectacularly, eroded by the major streams which have formed canyons, peculiarly shaped erosional remnants and numerous outliers.

Edwards Plateau Section: The Edwards Plateau in the Brazos River area is represented by outliers and edges occurring along the south border of the basin from Nolan County to Travis County. It is composed of resistant limestone formations overlain by thin soils, and its average rates of erosion and sediment output are low. One prominant occurrence is an outlier extending roughly east and west through Nolan, Taylor and Callahan counties, and is commonly called the Callahan Divide.

The formations underlying the plateau are correlative with those of the Lampasas Cut Plain and the Grand Prairie further north. Northward from Travis County the formations decrease in thickness and limestone content and the topography merges gradually into that of the Lampasas Cut Plain and Grand Prairie.

Central Lowland Province

The Central Lowland Province extends from the eastern margin of the High Plains (in Dickens, Garza and Crosby counties) about 200

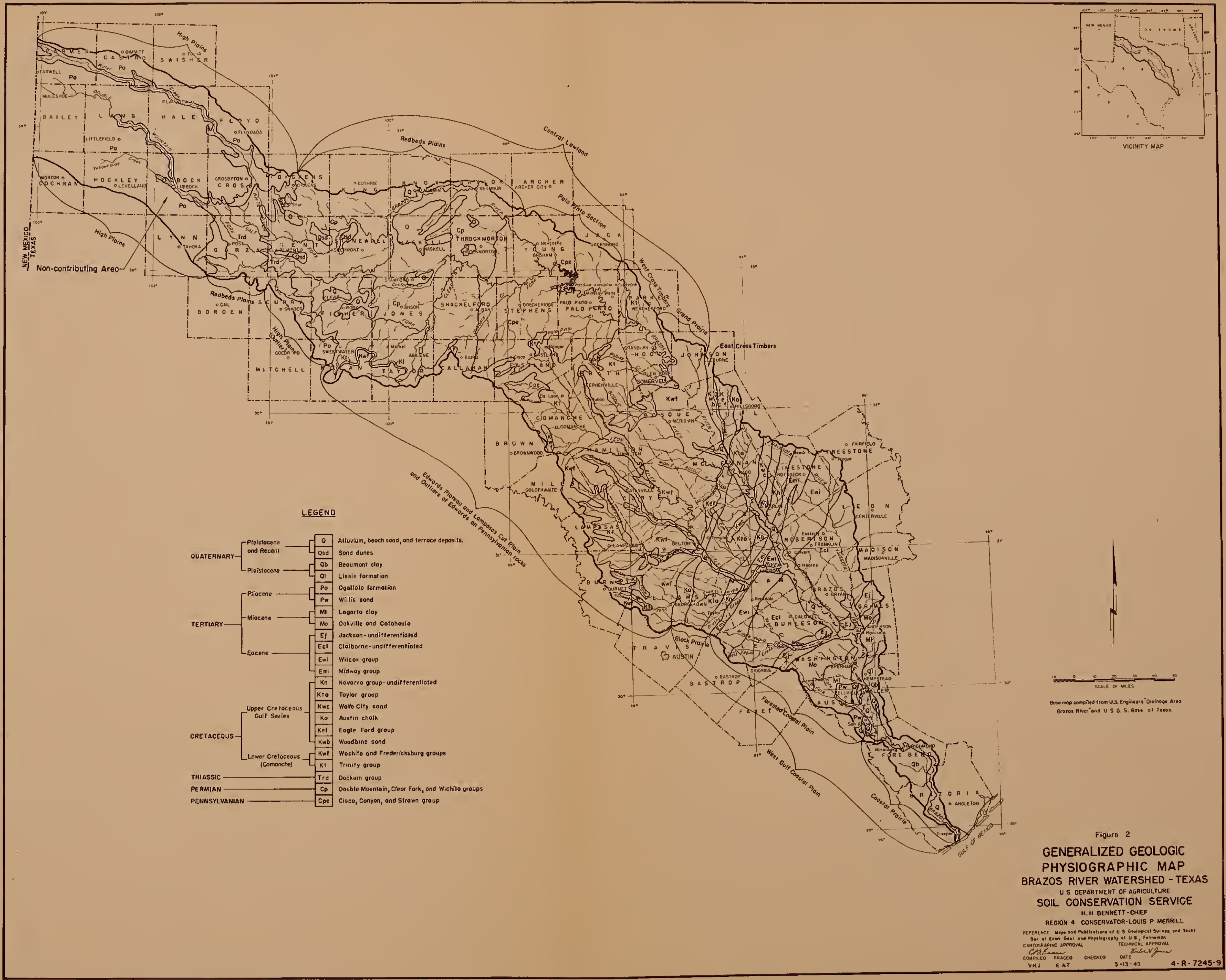


Figure 2

GENERALIZED GEOLOGIC PHYSIOGRAPHIC MAP
BRAZOS RIVER WATERSHED - TEXAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P MERRILL

REFERENCE: Maps and Publications of U S Geological Survey, and Texas Bur of Econ Geol and Physiography of U.S., Fenneman
CARTOGRAPHIC APPROVAL TECHNICAL APPROVAL
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miles southeasterly to Johnson County and includes nearly one-half of the Brazos River Drainage Area. It is a large and diverse area which includes much rough topography. The drainage is well-developed and the topography ranges from gently undulatory to mountainous. The Central Lowlands includes parts of 4 subdivisions: (1) the Redbeds Plains, (2) the Palo Pinto Section, (3) the West Cross Timbers and (4) the Grand Prairie. It contains rock formations ranging in age from Pennsylvanian to Recent and rates of erosion range from the highest to nearly the lowest in the Brazos River Watershed.

Redbeds Plains Section: The Redbeds Plains section occupies about one-fifth of the Brazos River Watershed area in a roughly rectangular section (figure 2). It has well-drained rolling topography in which stream gradients are relatively high. The bluffs along Salt Fork, Double Mountain Fork and Clear Fork range from 100 to 200 feet in height and even the bedrock valley walls are subject to considerable lateral erosion by the main streams.

Two systems of rock formations in general underlie the area. At the west margin in Crosby, Garza and Dickens counties the chief country rock is the Dockum formation of Triassic age. The remainder of the Redbeds area in underlain by Permian formations. All of the formations are predominantly reddish in color and consist chiefly of silts and sands with some moderately cemented sandstones and much gypsum. The land surface is interrputed by numerous outliers of younger formations such as the Ogallala and later dune sand and some mesas of Cretaceous rocks. In general the Redbeds Plains are subject to serious accelerated erosion, especially gully development, and they are poor sources of ground water.

Palo Pinto Section: The Palo Pinto section extends southeasterly across the drainage area in a belt about 60 miles wide from Young and Jack counties to Eastland and Callahan counties. It is an area of ridged topography with relatively high relief and many scenic features. The bluffs around Possum Kingdom Reservoir range from 200 to 400 feet in height. The Brazos River valley has entrenched meanders through much of this section, resembling some Appalachian Mountain valleys. Tributary valleys have steep gradients, and their courses are controlled by rock structure.

The main ridges are capped by resistant sandstones and limestones, and the tributary valleys have been developed in shales. Rates of erosion are relatively low, with local exceptions in areas of softer sandstones and shales. Three series of rocks of Pennsylvanian age (Strawn, Canyon and Cisco) underlie the Palo Pinto Section, and some bituminous coal is produced from the lower beds in local mines. This section corresponds roughly to the Reddish Prairie conservation problem area.

West Cross Timbers Section: The West Cross Timbers occupies parts of Parker, Somervell, Erath and Comanche counties. The area has generally undulatory topography, an average local relief of about 100 feet, and thorough, dendritic drainage. It is underlain by the unconsolidated and easily-eroded Paluxy and Basement sands of Trinity (Lower Cretaceous) age which afford good ground water resources. Development of modern gullies has followed cultivation without erosion control. As a consequence gullied areas in uplands are common, while heavy deposition of eroded sand in many tributary streams, disturbance of ground water levels and reduction in bottomland productivity has occurred.

Grand Prairie and Lampasas Cut Plain Section: Typical Grand Prairie, with a gently undulating topography and relatively shallow valleys, occurs in Johnson and parts of Bosque and Hill and other counties. South from this area, however, the Grand Prairie is progressively rougher with high relief, deeper valleys and bluff-like prominences which increase in height to the south boundary of the watershed in Lampasas and Burnet counties. The southern part of this area is known locally as the Lampasas Cut Plain. It has many characteristics of a plateau including high, flat upland divides, steep valley bluffs and a generally table-like topography. From Travis County to Lampasas County the Lampasas Cut Plain merges with the Edwards Plateau.

Streams in this section have relatively steep gradients and rapid runoff. The channels are characterized by bars of limestone gravel, generally clear water and relatively straight courses. Rocks underlying the Grand Prairie and Lampasas Cut Plain are the Trinity, Washita, and Fredericksburg groups of Lower Cretaceous age (figure 2). They contain nearly equal proportions of shales and limestones in Johnson County and become increasingly calcareous southward. In general this section is relatively resistant to erosion, and sedimentation damages are not serious.

## West Gulf Coastal Plain Province

The western boundary of outcrop of the Upper Cretaceous rocks is the boundary between the Central Lowlands and West Gulf Coastal Plains Provinces. Southeasterly from this boundary the topography generally is more subdued, valleys are wider and shallower, and rock formations are generally less indurated. Erosion rates are generally higher than in limestone areas upstream.

East Cross Timbers: The East Cross Timbers occupies a narrow strip about 5 miles wide extending roughly southward through Cleburne and Hill counties. It has relatively rough topography but low relief and has minimum importance in the Brazos River Watershed. It is underlain by the Woodbine sand of Lower Cretaceous age.

Black Prairie: The Black Prairie, corresponding to the Blackland Prairie conservation problem area, extends across the Brazos River Watershed from Hill and Limestone counties on the north through Williamson County on the south, and has an average width of about 35 miles. It is a belt characterized by long gentle slopes, dark clay soils of high fertility, and well-developed drainage. Local relief in most places does not exceed 80 feet. High bluffs occur along the streams, especially the Little River and the Brazos River, and conspicuous ridges have resulted from differential erosion in the vicinity of a few resistant formations, chiefly the Austin chalk and the Pecan Gap chalk.

The rock formations underlying the Black Prairie belong to the Upper Cretaceous system having gentle southeasterly dips, and consist chiefly of marls, calcareous clays and chalks. Only one sandy formation, the Wolfe City sand, is present in this area. It is a belt of outcrop about 5 miles wide extending through parts of Limestone, McLennan and Falls counties. Intensive cultivation has resulted in very rapid filling of reservoirs with sediment (table 27, Appendix IV) clogging of stream channels in upland tributaries and frequent burial of crops by flood-deposited sediment.

Forested Coastal Plain: The Forested Coastal Plain includes a large roughly triangular area extending from Freestone and Williamson counties on the west to Austin and Waller Counties in the east. It has generally subdued relief, wide but shallow stream valleys, and predominantly gentle slopes. The Brazos River from near Calvert in Robertson County flows toward the Gulf across alternating belts of predominantly sandy and predominantly clay type soils. These reflect the characteristics of the underlying Tertiary formations including the Midway, Wilcox, Claiborne and Jackson formations of Eocene age and the sands and clays of Miocene and Pliocene age (figure 2).

The Forested Coastal Plain, therefore, has a great variety of topography, vegetation and rates of erosion. Locally erosion in sandy formations is serious and causes damaging deposition in some stream valleys. Low average gradients and abundant vegetation, however, prevent the development of extremely rapid accelerated erosion in most parts of the Forested Coastal Plain.

Coastal Prairie: A narrow belt of low, flat coastal prairie is drained by the Brazos River and a few minor tributaries below Rosenberg. Two principal rock formations, the Beaumont clay and Quaternary alluvium underlie this section. The valleys are broad and shallow, swampy conditions are common and only minor interruptions occur on the flat plain.

## CLIMATIC FACTORS

The climate is moderate. The average annual temperature ranges from about 70 degrees in the coastal regions to about 57 degrees in the upper portions of the watershed. Summers are long with high day and moderate night temperatures. Normally the winters are short and mild. Subzero temperatures have been recorded in the upper portion of the watershed during December, January, and February but such low temperatures are infrequent. The average minimum during January ranges from 44 degrees near the coast to about 21 degrees near the headwaters. The growing season normally extends from the latter part of March to the middle of November.

The annual rainfall over the 35,720 square miles of contributing drainage area is about 29.5 inches. The average annual precipitation is about 47 inches near the coast and ranges downward to 16 inches in the headwaters.

Periods of drought are common. During 1917 the average rainfall was about 15 inches. During the 4 year period from 1909 to 1912 the total rainfall was about 25 inches below normal.

As about seventy-five percent of the rainfall occurs during the growing season the distribution of rainfall is generally favorable. Extended summer droughts are common in all areas of the watershed.

## SUBWATERSHEDS

For convenience in hydrologic evaluation the watershed was divided into 26 subwatersheds (figure 3). Wherever possible each subwatershed consists of a major tributary alone but along the main stream of the Brazos a subwatershed may include many short tributaries which enter a reach between major tributaries or between control points such as constructed or authorized reservoirs. In other cases the location of an authorized reservoir on a tributary caused the separation of the tributary drainage into two subwatersheds.

The area of the conservation problem areas included within each subwatershed is shown in table 1.

## LAND USE

The percentages of various land uses are shown by conservation problem areas in table 3 and by subwatersheds in table 4. Data were obtained from the Conservation Job Ahead Study completed by the Soil Conservation Service in 1945. Census reports were used to verify these figures.


Figure 3

SUBWATERSHED DRAINAGE AREAS
BRAZOS RIVER WATERSHED - TEXAS

Table 3. Percentage of Various Land Uses by Conservation Problem Areas

Brazos River Watershed

| Conservation Problem Area | Land in Farms | Land in Farms: Cultivated | Grassland | Pastured Woodland | Miscellaneous |
|---|---|---|---|---|---|
| | (percent) | (percent) | (percent) | (percent) | (percent) |
| High Plains | | | | | |
| Northern Area | 97.4 | 88.8 | 9.5 | - | 1.7 |
| Southern Area | 97.1 | 86.5 | 12.2 | - | 1.3 |
| Rolling Red Plains | | | | | |
| Western Area | 99.0 | 25.0 | 74.4 | - | 0.6 |
| Central Area | 96.2 | 52.4 | 45.4 | - | 2.2 |
| Edwards Plateau | 94.2 | 6.9 | 91.7 | - | 1.4 |
| Reddish Prairie | 95.4 | 25.0 | 67.0 | 7.1 | 0.9 |
| Cross Timbers | 96.6 | 27.8 | 68.8 | 2.0 | 1.4 |
| Grand Prairie | 98.2 | 25.1 | 69.3 | 4.6 | 1.0 |
| Blackland Prairie | | | | | |
| Central Areas | 96.9 | 73.8 | 21.0 | 2.3 | 2.9 |
| Southern Area | 96.2 | 35.1 | 57.6 | 5.0 | 2.3 |
| Forested Coastal Plain | | | | | |
| Eastern Area | 98.1 | 30.0 | 54.6 | 13.8 | 1.6 |
| Western Area | 97.4 | 22.0 | 60.9 | 15.0 | 2.1 |
| Coast Prairie | 95.9 | 26.0 | 71.5 | - | 2.5 |
| Bottomland | | | | | |
| Main Brazos | 96.6 | 63.7 | 30.0 | 3.9 | 2.4 |
| Navasota | 98.8 | 12.5 | 66.3 | 20.1 | 1.1 |

Table 4. Percentages of Various Land Uses by Subwatersheds
Brazos River Watershed

| Subwatershed | Total Area | Land in Farms | Land in Farms: Cultivated | Grassland | Pastured Woodland | Miscellaneous |
|---|---|---|---|---|---|---|
| | (sq. mi.) | (percent) | (percent) | (percent) | (percent) | (percent) |
| Non-contributing | 6,419 | 97.1 | 86.5 | 12.2 | - | 1.3 |
| White River | 543 | 98.2 | 59.4 | 39.4 | - | 1.2 |
| Salt Fork | 1,935 | 99.0 | 26.0 | 73.0 | - | 1.0 |
| Double Mountain Fork | 2,133 | 98.8 | 29.7 | 69.7 | - | 0.6 |
| Elm Creek | 489 | 95.6 | 39.2 | 58.9 | - | 1.9 |
| Hubbard Creek | 1,274 | 95.2 | 22.5 | 70.5 | 6.1 | 0.9 |
| Clear Fork | 2,905 | 95.5 | 35.7 | 61.6 | 0.9 | 1.8 |
| California Creek | 1,064 | 96.0 | 47.5 | 50.4 | - | 2.1 |
| Brazos above Possum Kingdom | 2,528 | 97.3 | 22.6 | 74.5 | 0.2 | 0.8 |
| Possum Kingdom | 1,085 | 92.5 | 21.8 | 61.4 | 15.5 | 1.3 |
| Palo Pinto Creek | 628 | 96.4 | 22.4 | 58.4 | 17.9 | 1.3 |
| Possum Kingdom to Whitney | 2,168 | 93.6 | 22.2 | 60.9 | 14.8 | 2.1 |
| Paluxy Creek | 432 | 97.9 | 17.2 | 43.1 | 37.8 | 1.9 |
| Whitney to Waco | 280 | 98.1 | 33.1 | 51.3 | 12.9 | 2.7 |
| Nolands River | 330 | 98.3 | 36.3 | 50.2 | 10.8 | 2.7 |
| Aquilla Creek | 417 | 97.4 | 57.3 | 33.7 | 6.6 | 2.4 |
| Bosque River | 1,676 | 89.7 | 42.0 | 42.0 | 15.0 | 1.0 |
| Waco to Little River | 1,495 | 97.0 | 69.6 | 24.3 | 3.3 | 2.8 |
| Little River 1/ | 7,373 | 97.8 | 40.1 | 43.0 | 14.7 | 5.9 |
| Little River to Irrigation | 1,634 | 96.6 | 35.1 | 55.9 | 6.7 | 2.3 |
| Little Brazos | 658 | 97.7 | 42.9 | 44.8 | 10.3 | 2.0 |
| Yegua above dam | 1,012 | 94.0 | 24.6 | 59.8 | 13.4 | 2.2 |
| Yegua below dam | 319 | 97.2 | 22.0 | 55.2 | 20.8 | 2.0 |
| Navasota above dam | 1,782 | 94.8 | 41.9 | 44.3 | 11.8 | 2.0 |
| Navasota below dam | 395 | 97.8 | 27.9 | 50.6 | 19.9 | 1.6 |
| Mill Creek | 398 | 96.4 | 31.7 | 59.9 | 6.1 | 2.3 |
| Irrigation to Mouth | 625 | 97.2 | 43.2 | 54.4 | - | 2.4 |
| Total | 41,997 | 95.7 | 44.4 | 47.1 | 7.2 | 1.3 |

1/ Little River Survey Report uses 7,545 square miles as total area. 7,373 agrees with USED area.

## DETERMINATION OF PRESENT PHYSICAL CONDITIONS

### Soil Slope and Erosion Conditions

Tabulations of conservation survey data were completed for over 6,000,000 acres which has been mapped within and adjoining the watershed (table 5). In these tabulations soil units were grouped on the basis of similar characteristics. The percentages of such groups within each conservation problem area are shown in the following tabulation.

| High Plains | Percentage of Area |
|---|---|
| Deep, fine textures, moderately permeable | 72 |
| Deep, medium textured, permeable | 17 |
| Shallow | 5 |
| Miscellaneous | 6 |
| **Rolling Red Plains (Western Area)** | |
| Deep, fine textured, slowly permeable | 27 |
| Deep, medium textured, moderately permeable | 20 |
| Shallow | 25 |
| Sand hills | 13 |
| Miscellaneous | 15 |
| **Rolling Red Plains (Central Area)** | |
| Deep, fine textured, slowly permeable | 59 |
| Deep, medium textured, moderately permeable | 13 |
| Shallow | 14 |
| Alluvial | 9 |
| Miscellaneous | 5 |
| **Edwards Plateau** | |
| Deep, fine textured, slowly permeable | 29 |
| Shallow | 24 |
| Shallow and stony | 42 |
| Alluvial | 5 |
| **Reddish Prairie** | |
| Deep, fine textured, slowly permeable | 29 |
| Medium textured, moderately permeable | 24 |
| Shallow and stony | 38 |
| Alluvial | 9 |

| Cross Timbers | Percentage of Area |
|---|---|
| Deep, medium textured, moderately permeable | 56 |
| Coarse textured, permeable | 33 |
| Miscellaneous | 11 |
| **Grand Prairie** | |
| Deep, fine textured, slowly permeable | 35 |
| Shallow | 31 |
| Shallow and stony | 26 |
| Miscellaneous | 8 |
| **Blackland Prairie** | |
| Deep, fine textured, slowly permeable | 62 |
| Deep, fine textured, permeable | 8 |
| Shallow | 5 |
| Alluvial | 15 |
| Miscellaneous | 10 |
| **Forested Coastal Plain** | |
| Deep, medium textured, moderately permeable | 67 |
| Coarse textured, permeable | 16 |
| Alluvial | 16 |
| Miscellaneous | 1 |
| **Coast Prairie** | |
| Deep, fine textured, slowly permeable | 78 |
| Deep, medium textured, slowly permeable | 20 |
| Alluvial | 2 |

Slope and erosion conditions were tabulated and combined by separate land uses and soil groups into three classes as follows:

1. Conditions which require only simple conservation measures for continued use.

2. Conditions which require complex and expensive conservation measures for continued use as cropland or maintenance in pasture.

3. Conditions which preclude the use of the land for cultivation and require complex measures to re-establish or maintain vegetative cover.

Table 5. Sources of Data Used in Calculation of Physical Conditions

Brazos River Watershed

| Conservation Problem Area | Little River 1/ (acres) | Bosque River 2/ (acres) | Brazos River 1/ (acres) | Total (acres) |
|---|---|---|---|---|
| | | Conservation Surveys | | |
| Coast Prairie | - | - | 24,957 | 24,957 |
| Forested Coastal Plain | 84,600 | - | 218,958 | 303,558 |
| Blackland Prairie | 408,900 | 12,588 | 407,030 | 828,518 |
| Grand Prairie | 568,100 | 91,796 | - | 659,896 |
| Cross Timbers | 122,900 | - | - | 122,900 |
| Reddish Prairie | 33,200 | - | 438,715 | 471,915 |
| Edwards Plateau | - | - | 354,832 | 354,832 |
| Rolling Red Plains | - | - | 2,123,645 | 2,123,645 |
| High Plains | - | - | 1,349,247 | 1,349,247 |
| Total | 1,217,700 | 104,384 | 4,917,384 | 6,239,468 |
| | | Cover Condition Classification 2/ | | |
| Open grass | 61,000 | | | |
| Oak-Juniper | 66,000 | | | |
| Browse-shrub | 14,000 | | | |

1/ Tabulated from detailed conservation surveys in Soil Conservation Districts in and adjacent to the watershed.

2/ Tabulated from field surveys by the party within the watershed.

This tabulation and the use of land capability tabulations 1/ within the soil conservation districts of the watershed furnished a measure of the outstanding characteristics of the conservation problem areas. The percentages within each conservation problem area occupied by various complexes of soil, slope and erosion which require certain measures are shown in table 6.

Description of Vegetative Cover

During the course of field work in the Little River Survey 2/ over 140,000 acres of grasslands were classified by a field survey. The results of this survey were found, by a reconnaissance field check, to be applicable to the pasture and woodland conditions within the same conservation problem areas of the Brazos River Watershed.

In the remaining areas the collected information from range specialists assisting the soil conservation districts was used to determine the present conditions. The method used for this collection and analysis is given in Appendix VI. A brief description of the vegetation at present in the areas follows.

High Plains: On the heavy tight soils the climax type of mixed prairie formerly occupied the High Plains. Mixed short- and mid-grasses of blue grama and buffalograss with an overstory of western wheat grass predominated. Where the soils were shallower or lighter in texture, the short grasses were present but the western wheat grass gave way to needle and thread, sideoats grama and sand dropseed. As grazing pressure increased the mid-grasses were subdued and buffalograss became dominant over blue grama. In the severely grazed sites the annual weeds such as Russian thistle, lambs quarter and little barley replaced the buffalograss.

In the sandy section of the High Plains, in addition to the same vegetation as in the sandy portion of the Rolling Red Plains, New Mexico feathergrass and sand dropseed is prevalent. More desert influence is apparent in the shrubs and as the site is drier there are fewer tall grasses. Under heavy grazing use yucca, shinnery oak, sand sage, and sumac has rapidly increased.

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1/ Classifying the Land for Conservation Farming, Farmer's Bulletin Number 1853.

2/ U. S. Department of Agriculture Interim Survey Report, Brazos River & Tributaries, Texas. Little River Watershed 1950.

Table 6. Characteristics of Conservation Problem Areas as Shown by Soil, Slope and Erosion Conditions

Brazos River Watershed

| Conservation Problem Area | Cultivated | Cultivated land suitable for pasture 1/ | Cultivated land needing complex treatment 2/ | Farm area capable of being cultivated 3/ | Farm area capable of cultivation if drained 4/ | Woodland which should not be cleared for pasture due to slope or shallow soil 5/ |
|---|---|---|---|---|---|---|
| | (percent) | (percent) | (percent) | (percent) | (percent) | (percent) |
| High Plains | 87 | 11 | 15 | 93 | 4 | - |
| Rolling Red Plains (Western Area) | 25 | 21 | 36 | 38 | 4 | - |
| Rolling Red Plains (Central Area) | 52 | 12 | 45 | 60 | 7 | - |
| Edwards Plateau | 7 | - | 17 | 26 | - | - |
| Reddish Prairie | 25 | 6 | 38 | 61 | 3 | 21 |
| Cross Timbers | 28 | 19 | 49 | 48 | 11 | 31 |
| Grand Prairie | 25 | 14 | 32 | 44 | 3 | 30 |
| Blackland Prairie (Central Area) | 74 | 8 | 42 | 87 | 6 | 19 |
| Blackland Prairie (Southern Area) | 35 | 8 | 71 | 74 | 7 | - |
| Forested Coastal Plain (East of river) | 30 | 7 | 57 | 84 | 7 | 2 |
| Forested Coastal Plain (West of river) | 22 | 10 | 83 | 78 | 3 | 6 |
| Coast Prairie | 26 | 12 | 52 | 73 | 3 | - |
| Bottomland | 64 | - | - | 76 | 24 | - |

1/ Capability class IV through VIII, This should be retired to grassland.
2/ Capability class III
3/ Capability class I, II, & III
4/ Capability class IV & V, will require severe restrictions.
5/ Survey investigation on class VII & VIII

In the depression ponds several associations are present. In the extremely wet or long-lived lakes aquatic grasses and sedges are prevalent while on those that dry out slowly smart weed and other annuals are noted. These produce little forage but if the lakes are drained or protected the soil will support buffalograss and western wheat grass meadows. The grass may be killed back during wet periods but the buffalograss will recover as the lake dries and the wheat grass will reseed naturally to form valuable grazing areas. In the few salty lakes the dominant grass is alkali sacaton.

At the edge of the High Plains on the escarpment there is some little bluestem, sideoats grama, hairy grama, hairy triodia and low grade annuals and forbs. This area is a poor site for range grasses but is not too severely grazed due to its inaccessibility.

Rolling Red Plains: This territory is the meeting ground of the true prairies (tall grasses) of the east and the mixed prairie of the west. Originally, on the normal soils, little bluestem, sideoats grama, hairy grama, blue grama, and buffalograss were the predominant association. The southwestern desert plains influence was shown in some areas by tobosa grass. Degeneration of the grass cover has been rapid. Sideoats grama and little bluestem have nearly disappeared while buffalograss, blue grama and tobosa grass have become the dominant grasses along with an extremely heavy invasion of sand sage and mesquite.

There is some western wheat grass in the valleys and alkali sacaton has often replaced the bluestem and sideoats grama in the "salty" valleys. Poor quality annual weeds have replaced much of the original grass.

In the sandhill areas a luxuriant growth of medium and tall grasses was originally present and utilized the favorable water relationships in the deep, loose soils. Switch grass, indiangrass, little bluestem, giant sand reed, and sand love grass, sand bluestem, panicums and needle and thread grass dominated the sites. Small amounts of shinnery oak, sumac and yucca were present. Under present heavy use the tall- and mid-grasses have largely disappeared, the shrubs have greatly increased and the low quality grasses and forbs are about all that remain. Dwarf forests of shinnery oak and sumac have often replaced the grasses. This has had little effect on water relationships but has seriously lowered the grazing capacity of the area.

In the rough and broken areas, such as the Croton breaks along Croton Creek, relicts of the original vegetation are reasonably common due to their isolation and the protective topography. The major grasses were sideoats and hairy gramas, some little bluestem, and blue grama, and sand bluestem. In most of the area,

however, the grasses have been replaced by a scant growth of low quality forbs, hairy triodia and redberry juniper. Yucca, stunted trees and shrubs have increased rapidly. Some areas under heavy grazing use have been practically denuded and no protection against rapid soil and water losses is left. The entire area is a sediment source area and rapid geologic erosion is so intermingled with accelerated erosion that determination of the cause of sediment production is difficult.

Edwards Plateau: This area is characterized by open grassland, smoothly rolling topography and soils developed from limestone parent materials. This is one of the best remaining grazing areas in the watershed with a large percentage classed as being in good condition. The original vegetation of little bluestem, hairy grama, sideoats grama, tall dropseed, some big bluestem and indiangrass, and scattered liveoak has been replaced by buffalograss on the better sites and hairy triodia and threeawns with numerous annual weeds on the shallower and poorer sites. Mesquite has become very widespread and the infestation varies from a few scattered trees to a very heavy growth of large trees which have practically shaded out the grasses. Cedar and liveoak have invaded on some of the "breaks" and shallow soils.

While cover conditions are conducive to rather rapid rates of water intake into the soil, further improvement may be accomplished by leaving on the surface larger amounts of residue from the grass crop through better management practices. Utilization of the forage has been complete for many years and the surface litter on the soil has deteriorated considerably from the most desirable condition. Very little damage from soil erosion is suffered at the present time.

Reddish Prairie: (1) Pastured woodland. The woodland in the Reddish Prairie usually occupies the numerous steep slopes and ridges. The oaks compose a tenth of the understory vegetation while mesquite occupies less than one percent. Post oak and blackjack oak are near the western margin of their range and are small and scrubby. Buffalograss, Texas wintergrass, perennial threeawns, hairy grama and annual brome grass usually form the rather sparse ground cover. Bluestems are present and where the ridges have been cleared often become the dominant grass species. Due to unrestricted grazing, many areas support very little grass cover under the woody shrub and tree growth.

(2) Grassland. The grassy prairies have been invaded, almost without exception, by the common mesquite. The prairies are found on areas of gentle relief and the grass vegetation is predominately of buffalograss. Little barley, Texas wintergrass, perennial threeawns, hairy grama, and vine-mesquite are among the other dominant grasses. Bluestems are nearly always present and

increase rapidly under careful grazing practices.

Continuous and heavy grazing has destroyed the character of the original cover and has resulted in the sparse grass cover now present. Trampling as well as grazing on the shaly clay soils have compacted the surface layers. This compaction has increased the amount of runoff during storms and inhibited the growth of the remaining grasses.

Cross Timbers 1/: (1) Woodland. The native vegetation of the Cross Timbers of the Brazos River Watershed consist principally of a dense stand of scrubby post-oak and blackjack oak, in which a few small open areas appear. Only traces of grass vegetation may be found growing in the heavily shaded and pastured woodlands.

In the openings panicums, lovegrasses, sand dropseed, annual fescue, Texas grama and traces of little bluestem and threeawns are present. The annual weeds, consisting chiefly of fluffweeds and plantains, occur in quantity.

Overgrazing and uncontrolled burning have destroyed much of the original ground cover, and the protection afforded against water and soil losses has severely deteriorated.

(2) Grassland. Many small fields have been retired from cultivation because of erosion and decreased soil fertility. These areas, at least those which have been retired for some years, support a thin stand of the grasses and weed species mentioned above plus sandburr and fillaree.

Grand Prairie: (1) Woodland. The area termed woodland is used for pasture and is covered with a moderate stand of live oak, Texas red oak, cedar and associated woody species. The grass vegetation which occurs in the openings and amid the bushy growth is very similar to that of the open pasture with little bluestem and grama occurring more frequently. The grasses, hairy grama, threeawns, triodia, sand dropseed, Texas wintergrass, and little bluestem are common except in areas containing large amounts of brush.

Cedar is increasing in density and spreading even into the open areas under present management. Many areas have been cleared of woody vegetation and are maintained as open pasture at the present time (about 20 percent of the open pasture which occurs in the wooded section has been cleared recently.) Heavy grazing in

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1/ The Vegetation of the Western Cross Timbers, E. J. Dyksterhuis, Ecological Monographs, 18:325-376, July, 1948.

wooded areas, along with indiscriminate cutting and burning, has greatly reduced the water retarding effect of the trees and litter. Once destroyed, the woody cover is not immediately replaced with grass cover.

(2) Grassland. This is usually found in the western sections on smoothly rolling topography and on moderately shallow soils. The rougher areas along the creeks and on abrupt slopes often support thickets of oak or cedar.

The continuous overgrazing of this open grassland during the past forty or fifty years has caused a serious decrease in the density of the desirable grasses (little bluestem, buffalograss, and the gramas). The decrease in these grasses is concurrent with a rapid increase in the less desirable species (threeawns, Texas wintergrass, muhly grasses, hairy triodia, and rescuegrass) along with an increase in annual weeds and invasion of cedar and other scrubby trees.

At present, the protection against soil and water losses offered by the vegetation is far below the maximum which the vegetative type should afford.

Blackland Prairie: (1) Grassland. The vegetation consists principally of buffalograss, Texas wintergrass, threeawns, gramas, and bluestem grasses. Annual weeds include plantains, filaree and broomweed. The grasslands used for pastures are usually small in extent and heavily grazed most of the year. Many abandoned areas along drains or gullies are solid bermudagrass or johnsongrass. There are a few native bluestem meadows still showing the nature of the original vegetation.

(2) Woodland. This heavily pastured type is characterized by a scattered stand of live oak and mixed hardwoods. The herbaceous vegetation consists principally of buffalograss, Texas wintergrass, little bluestem, threeawns, and rescuegrass. Annual weeds usually found include plantains, wild carrot and broomweed.

Forested Coastal Plain: (1) Pastured woodland. The woody vegetation consists of an overstory of elm, oak, hackberry, hickory, and other hardwood trees ranging in density from almost solid ground cover to scattered stands with numerous open glades. The herbaceous vegetation is comprised principally of bermudagrass, paspalums, Texas grama, threeawns, lovegrasses and little barley and many forbs. The wooded areas are grazed and often burned. In many cases various shrubs and weeds completely cover the forest floor. Trampling, fire, and continuous grazing have seriously lowered the infiltration capacity in most of these areas.

(2) Grassland. Grassland or open pasture consists of isolated fields which were formerly cultivated but were retired from cropping because of erosion or decreasing fertility. The present vegetation usually consists of paspalums, bermudagrass, sand dropseed, threeawns, and associated grasses and weeds. The density is usually sparse and forage production very low. Barely adequate cover to reduce erosion losses is present and water losses remain high.

Coast Prairie: This is normally a flat treeless plain bordering the Gulf of Mexico and in the Brazos River Watershed consists of narrow strips on each side of the main Brazos alluvial plain. Near the mouth of the Brazos River, where tidewater affects are apparent, the vegetation is comprised of plants which are typical of marshy and salt water sites. The value of this salty vegetation for forage is very low and the coastal marsh is not considered as pasture area. The vegetation of the smooth and higher-lying sections near the Forested Coastal Plain is composed of paspalums, panic grasses, bluestems, dropseeds, threeawns, and some buffalograss. The grassland cover is dense and reasonably uniform and with the normally high rainfall produces heavily. Increased fertility of the soil, proper drainage of some low areas, and the introduction of leguminous pasture plants is necessary to make this section exceptionally productive as a range area. Heavy grazing has not harmed the cover from the standpoint of soil protection and water retention.

Some few rolling areas near the Forested Coastal Plain have suffered considerable deterioration of good vegetative cover due to heavy grazing on the sandy areas but soil losses are not excessive.

## Infiltration Rates

Infiltration tests have been made to determine the approximate rate of water intake into the various soil conditions under the many variations in vegetative cover. Table 7 shows the percentages of grassland and pastured woodland in the various conservation problem areas which have a high or maximum rate of water intake under present conditions of use and treatment. Cross-tabulation of more than 140,000 acres of detailed range survey data with conservation survey information was used to determine the percentages listed. Information as to range conditions in other areas not covered in detail were secured from range technicians in the field.

## Rate of Soil Loss

The Soil Conservation Service has estimated the rate of soil loss or land damage within each conservation problem area. In this study the unit area (an area in which physical and economic characteristics are homogeneous) was developed as the basis for

Table 7. Percentage of Grazing Area in Each Conservation Problem Area Which Now Has a Maximum Infiltration Rate

Brazos River Watershed

| Conservation Problem Area | Area now in open grassland | Open grassland with maximum rate | Area now in pastured woodland | Pastured woodland with maximum rate |
|---|---|---|---|---|
| | (percent) | (percent) | (percent) | (percent) |
| High Plains | 11 | 4.3 | - | - |
| Rolling Red Plains (Western area) 1/ | 74 | 5.9 | - | - |
| Rolling Red Plains (Central area) 1/ | 45 | 6.9 | - | - |
| Edwards Plateau 1/ | 92 | 10.8 | - | - |
| Reddish Prairie 1/ | 67 | 17.0 | 7 | 14.5 |
| Cross Timbers 1/ | 69 | 3.7 | 2 | 3.2 |
| Grand Prairie 1/ | 69 | 1.3 | 5 | 1.3 |
| Blackland Prairie (Central area) | 21 | 7.7 | 2 | 1.2 |
| Blackland Prairie (Southern area) | 58 | 9.2 | 5 | 1.2 |
| Forested Coastal Plain (east of river) | 55 | 5.9 | 14 | 6.1 |
| Forested Coastal Plain (west of river) | 61 | 6.6 | 15 | 6.7 |
| Coast Prairie | 72 | 33.0 | - | - |
| Bottomland (Navasota) | 66 | 14.1 | 20 | 4.1 |
| Bottomland (Brazos) | 30 | 14.1 | 4 | 4.1 |

1/ A large portion of the area is covered with mesquite brush which is classed as open grass.

calculations. The soil loss rates were adjusted by several factors which included the following, as dictated by conditions in the unit area:

1. Land use patterns, from census.

2. Soil loss rates, from the Experiment Stations.

3. Slope gradient factors, from the Experiment Stations.

4. Slope length factors, from the Experiment stations.

5. Storm pattern or intensity factors, from hydrologic records.

6. Historical information.

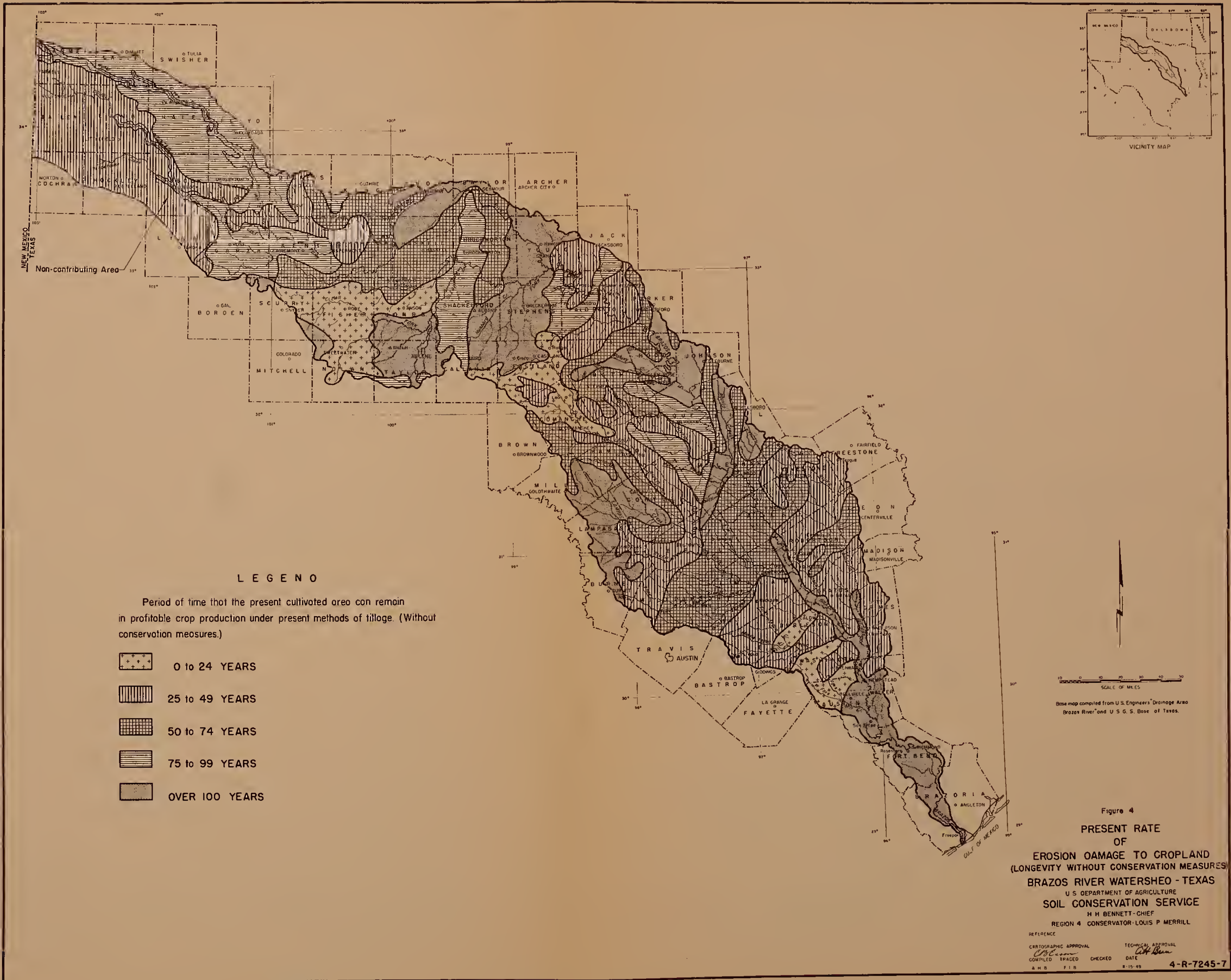
The annual amounts of soil loss from the various subwatersheds are shown in table 8 and the rate of land damage to cultivated areas shown in figure 4. The legend in figure 4 is based upon the period during which, under normal price levels, the presently cultivated land can be used for cultivation. It is estimated that the average cultivated field will revert to a less intensive use due to decreased productive capacity, caused by loss of topsoil, at or near the end of the period listed.

Table 8. Rate of Soil Loss by Subwatersheds

Brazos River Watershed

| Subwatershed | Drainage Area | Annual Soil Loss 1/ | Annual Soil Loss Per Square Mile |
|---|---|---|---|
| | (square mile) | (acre-feet) | (acre-feet) |
| Non-contributing | 6,419 | 8,215 3/ | 1.28 |
| White River | 543 | 350 | .64 |
| Salt Fork | 1,935 | 1,205 | .62 |
| Double Mountain Fork | 2,133 | 2,810 | 1.32 |
| Elm Creek | 489 | 675 | 1.37 |
| Hubbard Creek | 1,274 | 1,780 | 1.41 |
| Clear Fork | 2,905 | 3,430 | 1.19 |
| California Creek | 1,064 | 1,070 | 1.01 |
| Brazos above Possum Kingdom | 2,528 | 2,060 | .82 |
| Possum Kingdom | 1,085 | 1,380 | 1.97 |
| Palo Pinto Creek | 628 | 960 | 1.55 |
| Possum Kingdom to Whitney | 2,168 | 2,205 | 1.02 |
| Paluxy Creek | 432 | 485 | 1.12 |
| Whitney to Waco | 280 | 450 | 1.61 |
| Nolands River | 330 | 510 | 1.55 |
| Aquilla Creek | 417 | 1,135 | 2.72 |
| Bosque River | 1,676 | 2,860 | 1.71 |
| Waco to Little River | 1,495 | 4,900 | 3.29 |
| Little River | 7,373 2/ | 17,485 | 2.32 |
| Little River to Irrigation | 1,634 | 1,955 | 1.20 |
| Little Brazos | 658 | 1,105 | 1.68 |
| Yegua above dam | 1,012 | 1,375 | 1.36 |
| Yegua below dam | 319 | 485 | 1.52 |
| Navasota above dam | 1,782 | 3,320 | 1.87 |
| Navasota below dam | 395 | 690 | 1.75 |
| Mill Creek | 398 | 935 | 2.36 |
| Irrigation to mouth | 625 | 100 | .16 |
| Total | 41,997 | 63,930 | 1.52 |

1/ Unpublished data, Soil Conservation.
2/ 7,545 in Interim Report, Little River. 7,373 after Department of the Army, Corps of Engineers.
3/ Area in New Mexico excluded. Wind erosion not considered. 2532 sq. mi. of non-contributing areas are in New Mexico. 142 sq. mi. of White River are in New Mexico.


LEGEND
Period of time that the present cultivated area can remain in profitable crop production under present methods of tillage. (Without conservation measures.)
0 to 24 YEARS
25 to 49 YEARS
50 to 74 YEARS
75 to 99 YEARS
OVER 100 YEARS
Non-contributing Area
NEW MEXICO
TEXAS
VICINITY MAP
SCALE OF MILES
Base map compiled from U.S. Engineers' Drainage Area Brazos River and U.S.G.S. Base of Texas.
Figure 4
PRESENT RATE
OF
EROSION DAMAGE TO CROPLAND
(LONGEVITY WITHOUT CONSERVATION MEASURES)
BRAZOS RIVER WATERSHED - TEXAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H H BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P MERRILL
4-R-7245-7

# APPENDIX II

## LAND AND WATER ECONOMY

### SETTLEMENT

The earliest recorded permanent white settlement in the Brazos River Watershed occurred at Washington-on-the-Brazos in 1821, by colonists under the leadership of Stephen F. Austin. A few missions to the native Indians had preceded this settlement. The first counties were organized in 1836 and gained legal status in 1837. Among these were Austin, Brazoria and Washington. Settlement progressed westward up the Brazos River and rapid increases in population and agricultural development took place following the wars of 1848 and 1860. The last county, Hockley, was organized in 1924.

### POPULATION

The total population of the Brazos River Watershed in 1940 was about 1,040,000, a loss of about 10,000 or approximately one percent during the period from 1930 to 1940.

The urban population of the Brazos River Watershed was 330,787 in 1940, a gain of 41,873 from the 1930 urban population of 288,914. There were 43 urban communities (cities having a population of 2,500 or more) within the watershed in 1940 compared with 38 such communities in 1930. The largest city in the watershed was Waco, population 55,982 in 1940, followed by Lubbock, Abilene, Temple, and Bryan in the order named.

#### Rural Population

The rural population of the watershed was about 709,000 in 1940 as compared with about 761,000 in 1930. This change was due to a decrease in the farm population. Although about 10,000 of the decrease in rural population resulted from reclassifying five rural communities as urban in the 1940 census, the rural non-farm population increased during the decade. The population changes are listed in table 9.

Table 9. The Approximate Rural Farm, Rural Non-farm and Urban Population, 1930 and 1940. 1/

Brazos River Watershed

| Item | Population Census of: 1930 (number) | 1930 (percent) | 1940 (number) | 1940 (percent) | Change 1930 to 1940 |
|---|---|---|---|---|---|
| Rural Farm | 554,000 | 52.8 | 488,000 | 46.9 | -11.9 |
| Rural Non-farm | 207,000 | 19.7 | 221,000 | 21.3 | + 6.8 |
| All Rural | 761,000 | 72.5 | 709,000 | 68.2 | - 6.8 |
| Urban | 289,000 | 27.5 | 331,000 | 31.8 | +14.5 |
| Watershed Total | 1,050,000 | 100.0 | 1,040,000 | 100.0 | - 1.0 |

1/ U. S. Census, 1930 and 1940.

The density of the rural population in 1940 was approximately 16 per square mile, ranging from slightly below 10 in the High Plains area to about 33 in the area below Waco.

## Shifts of Farm Population

The rural farm population numbered about 488,000 in 1940, and was lower than the 554,000 in 1930 by almost 12 percent. Tabulations from the 1945 Census of Agriculture indicate that this trend has continued, although changes in definitions, methods of collection and date of enumeration prevent a direct comparison with earlier census information.

Substitution of machines for man and horse-power has created a condition where fewer farmers are needed to operate the farm acreage. Agricultural conservation programs have encouraged a reduction in cotton acreage and an increase in pasture.

Increased per capita farm incomes, accompanying the continued mechanization and increased owner operation of farm units, will aid in stabilizing the agricultural economy of the area and in the installation of the recommended program.

## CHANGES IS FARM VALUES AND SIZE OF FARMS

Changes in farm values usually reflect, after a lapse of a few years, fundamental changes which have taken place in the financial status of farming.

From 1930 to 1935 land values in all areas of the Brazos River Watershed declined sharply (table 10). This decline reflected the depressed condition of farming during this period which forced many farmers to adopt an exploitative system of farming. This exploitation accelerated erosion, produced conditions favorable to increased run-off and increased the flood hazards. After 1940, farm values and incomes increased rapidly (tables 10 and 11). As a result farmers now have less difficulty in meeting fixed charges and have more freedom of choice in organizing their farm enterprises. They are in a better financial position to adjust their businesses to meet any decline in prices of farm products and to increase efficiency of farm operations.

The average size of farms has been increasing in the Brazos River Watershed since 1930 (table 12). The increase has been general in all areas except the Edwards Plateau.

The increases in farm values and size of farms, if not accompanied by further inflation of land values or followed by depressed prices of farm products, are in the direction of a more stable agricultural economy in the watershed. Installation of the recommended program will aid in this desirable adjustment.

A number of war-induced changes in the farm economy of the watershed are offsetting the desirable trends to some extent. For example, during the war a sharp increase in the peanut acreage in the Cross Timbers area has increased the erosion loss from fields and the sediment hazard to areas downstream.

## LAND OWNERSHIP

Most of the land in the Brazos River Watershed is privately owned. Among the major publicly owned areas are Camp Hood (160,000 acres), the Bluebonnet Experiment Station Farm (15,000 acres) and Possum Kingdom State Park, (7,000 acres). There are a number of smaller state parks with an aggregate area of about 6,000 acres. Other publicly owned lands include the campus and Experiment Station of Agricultural and Mechanical College of Texas at College Station, several State Experiment Substations, and a number of municipal parks. There are no national forests within the watershed.

About 96 percent of the land area is in farms. In most counties in the watershed more than 80 percent of the area is in farms (table 13).

In all calculations involving acreage the non-farmland estimates made by the Soil Conservation Service in their conservation needs inventory (unpublished records) were used. These estimates were made for small areas and are considered a better expression of the acreage of treatable lands than can be derived from census data.

Table 10 - Average Value of Farmland and Buildings per Acre of Farmland in Counties Representative of Each Conservation Problem Area. 1/

Brazos River Watershed

| County | Conservation Problem Area | Average Value per Acre, Census of: 1930 | 1935 | 1940 | 1945 |
|---|---|---|---|---|---|
| | | (dollars) | (dollars) | (dollars) | (dollars) |
| Waller | Coast Prairie | 26.28 | 1935 | 25.60 | 33.74 |
| Brazos | | 34.36 | 21.96 | 26.45 | 26.44 |
| Lee | | 24.20 | 14.47 | 16.55 | 20.33 |
| Robertson | | 33.90 | 22.17 | 21.82 | 24.40 |
| Average | Forested Coastal Plain | 30.82 | 19.53 | 21.62 | 23.72 |
| Falls | | 80.25 | 44.17 | 44.92 | 49.08 |
| McLennan | | 82.95 | 44.35 | 45.22 | 51.73 |
| Washington | | 53.26 | 30.52 | 41.43 | 39.88 |
| Average | Blackland Prairie | 72.15 | 39.68 | 43.86 | 46.90 |
| Erath | | 22.02 | 13.33 | 14.37 | 24.33 |
| Eastland | | 23.13 | 11.79 | 13.21 | 20.94 |
| Average | Cross Timbers | 22.58 | 12.56 | 13.79 | 22.64 |
| Bosque | | 31.70 | 18.89 | 20.78 | 28.74 |
| Hood | | 22.37 | 16.04 | 17.50 | 27.91 |
| Somervell | | 17.89 | 11.85 | 11.79 | 11.50 |
| Average | Grand Prairie | 23.99 | 15.59 | 16.69 | 22.72 |
| Stephens | | 14.82 | 8.70 | 9.86 | 16.63 |
| Young | | 28.10 | 16.63 | 18.98 | 22.88 |
| Average | Reddish Prairie | 21.46 | 12.66 | 14.42 | 19.76 |
| Shackelford | Edwards Plateau | 18.76 | 13.86 | 13.56 | 21.15 |
| Fisher | | 40.46 | 21.30 | 24.08 | 33.77 |
| Haskell | | 45.41 | 29.25 | 27.37 | 44.27 |
| Kent | | 17.52 | 10.64 | 8.05 | 15.62 |
| Average | Rolling Red Plains | 34.46 | 20.40 | 19.83 | 31.22 |
| Bailey | | 26.14 | 17.56 | 17.57 | 31.32 |
| Hale | | 49.44 | 30.89 | 29.87 | 57.44 |
| Lamb | | 29.48 | 44.40 | 33.17 | 49.13 |
| Average | High Plains | 35.02 | 30.95 | 26.87 | 45.96 |
| Median of averages for all Conservation Problem Areas | | 26.28 | 19.35 | 19.83 | 23.72 |

1/ U. S. Department of Commerce, Census of Agriculture, 1935 and 1945.

Table 11 - Average Value per Farm of Farmland and Buildings in Counties Representative of Each Conservation Problem Area 1/

Brazos River Watershed

| County | Conservation Problem Area | Average Value per Farm, Census of: 1930 (dollars) | 1935 (dollars) | 1940 (dollars) | 1945 (dollars) |
|---|---|---|---|---|---|
| Waller | Coast Prairie | 3,521 | 3,893 | 3,833 | 6,911 |
| Brazos | | 3,692 | 2,993 | 4,433 | 4,632 |
| Lee | | 3,419 | 2,103 | 2,408 | 3,414 |
| Robertson | | 2,852 | 2,399 | 3,114 | 4,604 |
| Average | Forested Coastal Plain | 3,321 | 2,498 | 3,318 | 4,216 |
| Falls | | 5,693 | 3,758 | 4,956 | 6,353 |
| McLennan | | 7,357 | 4,737 | 5,755 | 7,046 |
| Washington | | 4,434 | 2,548 | 3,379 | 4,144 |
| Average | Blackland Prairie | 5,828 | 3,681 | 4,697 | 5,847 |
| Erath | | 4,573 | 2,693 | 3,219 | 5,265 |
| Eastland | | 4,038 | 2,016 | 2,697 | 4,532 |
| Average | Cross Timbers | 4,305 | 2,354 | 2,958 | 4,898 |
| Bosque | | 7,742 | 5,034 | 5,945 | 9,296 |
| Hood | | 4,889 | 3,431 | 4,189 | 8,384 |
| Somervell | | 3,302 | 2,369 | 2,581 | 2,861 |
| Average | Grand Prairie | 5,311 | 3,611 | 4,238 | 6,847 |
| Stephens | | 9,452 | 5,114 | 7,210 | 11,310 |
| Young | | 8,944 | 5,133 | 6,803 | 10,278 |
| Average | Reddish Prairie | 9,198 | 5,123 | 7,006 | 10,794 |
| Shackelford | Edwards Plateau | 21,190 | 14,374 | 16,520 | 19,017 |
| Fisher | | 9,539 | 6,162 | 7,938 | 12,736 |
| Haskell | | 10,014 | 6,861 | 7,735 | 13,670 |
| Kent | | 10,761 | 7,772 | 12,383 | 23,186 |
| Average | Rolling Red Plains | 10,105 | 6,932 | 9,352 | 16,531 |
| Bailey | | 13,677 | 8,250 | 9,695 | 18,487 |
| Hale | | 17,016 | 9,822 | 11,178 | 22,211 |
| Lamb | | 10,363 | 8,117 | 9,464 | 16,087 |
| Average | High Plains | 13,685 | 8,730 | 10,112 | 18,928 |
| Median of averages for all Conservation Problem Areas | | 5,828 | 3,681 | 4,697 | 6,911 |

1/ U. S. Department of Commerce, Census of Agriculture, 1935 and 1945.

Table 12 - Average Size of Farm in Counties Representative of Each Conservation Problem Area 1/

Brazos River Watershed

| County | Conservation Problem Area | Average Size of Farm, Census of: 1930 (acres) | 1935 (acres) | 1940 (acres) | 1945 (acres) |
|---|---|---|---|---|---|
| Waller | Coast Prairie | 134 | 150 | 150 | 205 |
| Brazos | | 108 | 136 | 168 | 175 |
| Lee | | 141 | 145 | 146 | 168 |
| Robertson | | 84 | 108 | 143 | 189 |
| Average | Forested Coastal Plain | 111 | 130 | 152 | 177 |
| Falls | | 71 | 85 | 110 | 129 |
| McLennan | | 89 | 107 | 127 | 136 |
| Washington | | 83 | 84 | 82 | 104 |
| Average | Blackland Prairie | 81 | 92 | 106 | 123 |
| Erath | | 208 | 202 | 224 | 216 |
| Eastland | | 175 | 171 | 204 | 216 |
| Average | Cross Timbers | 191 | 186 | 214 | 216 |
| Bosque | | 244 | 266 | 286 | 324 |
| Hood | | 218 | 214 | 239 | 300 |
| Somervell | | 185 | 200 | 219 | 249 |
| Average | Grand Prairie | 216 | 227 | 248 | 291 |
| Stephens | | 638 | 588 | 732 | 680 |
| Young | | 318 | 309 | 358 | 449 |
| Average | Reddish Prairie | 478 | 448 | 545 | 565 |
| Shackelford | Edwards Plateau | 1130 | 1037 | 1219 | 899 |
| Fisher | | 236 | 289 | 330 | 377 |
| Haskell | | 220 | 236 | 283 | 309 |
| Kent | | 614 | 731 | 1538 | 1485 |
| Average | Rolling Red Plains | 357 | 419 | 717 | 724 |
| Bailey | | 523 | 470 | 552 | 590 |
| Hale | | 344 | 318 | 374 | 387 |
| Lamb | | 233 | 275 | 285 | 327 |
| Average | High Plains | 367 | 354 | 404 | 435 |
| Median of averages for all conservation problem areas | | 216 | 227 | 248 | 291 |

1/ U. S. Department of Commerce, Census of Agriculture, 1935 and 1945.

Table 13 - Percent of Land in Farms, Representative Counties 1/
Brazos River Watershed

| County | Conservation Problem Area | Land in Farms, Census of: 1940 | 1945 |
|---|---|---|---|
| | | (percent) | (percent) |
| Waller | Coast Prairie | 68 | 76 |
| Brazos | Forested Coastal Plain | 80 | 85 |
| Lee | Forested Coastal Plain | 73 | 79 |
| Robertson | Forested Coastal Plain | 72 | 74 |
| Falls | Blackland Prairie | 87 | 88 |
| McLennan | Blackland Prairie | 85 | 88 |
| Washington | Blackland Prairie | 82 | 87 |
| Erath | Cross Timbers | 84 | 84 |
| Eastland | Cross Timbers | 78 | 83 |
| Bosque | Grand Prairie | 91 | 88 |
| Hood | Grand Prairie | 93 | 101 2/ |
| Somervell | Grand Prairie | 75 | 74 |
| Stephens | Reddish Prairie | 100 | 110 2/ |
| Young | Reddish Prairie | 90 | 100 |
| Shackelford | Edwards Plateau | 99 | 90 |
| Fisher | Rolling Red Plains | 84 | 102 2/ |
| Haskell | Rolling Red Plains | 96 | 96 |
| Kent | Rolling Red Plains | 121 2/ | 84 |
| Bailey | High Plains | 85 | 94 |
| Hale | High Plains | 97 | 92 |
| Lamb | High Plains | 92 | 94 |

1/ U. S. Census of Agriculture, 1945.

2/ The excess of farm acreage over land area is due to the fact that the entire acreage of a farm is tabulated as being in the county in which the headquarters is located, even though a part of the farm may be situated in an adjoining county.

## TENANCY

In 1930 about 49 percent of the farmland in the watershed was operated by tenants, but by 1945 this percentage had declined to 41 percent (table 14).

Table 14 - Percent of Farmland Operated under Each Type of Tenure 1/

Brazos River Watershed

| Tenure of Operator | Farmland, Census of: | | | |
|---|---|---|---|---|
| | 1930 | 1935 | 1940 | 1945 |
| | (percent) | (percent) | (percent) | (percent) |
| Owner | 39 | 43 | 45 | 50 |
| Tenant | 49 | 48 | 45 | 41 |
| Manager | 12 | 9 | 10 | 9 |
| Total | 100 | 100 | 100 | 100 |

1/ U. S. Census, 1930; U. S. Census of Agriculture 1935 and 1945

These data become important when consideration is given to the fact that land uses and farming practices on tenant-operated farms are often conducive to accelerated erosion and increased flood flows. Tenants use their farmland more intensively than owner-operators and are less inclined to cooperate in conservation programs designed to reduce soil loss and run-off. Therefore, the decrease in tenancy should facilitate obtaining farmer cooperation in the recommended program.

## LAND USE

The map (figure 5) shows the intensity of use for which each area is suited and the intensity of treatment needed to prevent further decline in value and productivity. These lands can support a permanent agriculture of the type recommended, provided the proposed type of use and treatments are adopted with reasonable promptness. Otherwise, severe damage may occur to present land resources.

## INDUSTRIES

Business enterprises closely connected with agriculture (such as cotton gins and compresses, grain elevators, and textile mills) have a major effect on the economy of the Brazos River Watershed, but other industries


Figure 5

RECOMMENDED LAND UTILIZATION BASED ON GENERAL LAND CAPABILITY CLASSIFICATION BRAZOS RIVER WATERSHED - TEXAS

U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H H BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P MERRILL

have considerable importance. The estimated production of oil in the watershed, during the year ending August 31, 1946, was about 38,000,000 barrels. There are about 18,500 wells 1/ located in the 38 oil-producing counties lying within or partially within the watershed. Pottery, brick, cement, coal, wallboard and various other products are locally important industrial enterprises. Large deposits of sulphur are mined in Brazoria and Ft. Bend counties and there are large undeveloped deposits of a variety of minerals in the watershed.

Electric power plants, having a combined generating capacity of about 116,000 kilowatts 1/, are located within the watershed. Thirteen railroad companies serve the area with main and branch lines while an adequate network of roads, power lines, oil and gas pipelines, and airlines extend throughout the watershed. Freeport Harbor and the Gulf Intercoastal Waterway provide ocean-going and barge navigation to the Freeport-Velasco area.

## SOIL CONSERVATION DISTRICTS

The Soil Conservation Service is furnishing technical assistance to the 48 soil conservation districts which are organized in the watershed. These districts embrace all but a few square miles in Comanche, Eastland and Taylor counties (figure 6). It is expected that within a few years the remaining area will be included within the present districts and will also be receiving technical assistance. Direct aid are presently available to every farmer in watershed through ACP administered by County & State P.M.A. committees

## RESERVOIRS, LEVEES AND OTHER IMPROVEMENTS

A plan has been recommended by the Department of the Army, Corps of Engineers, for several improvements on the Brazos River and tributaries for flood control, navigation and allied purposes. Construction has begun on Whitney Reservoir on the main Brazos River and at the Belton site on the Lower Leon River. In addition six reservoirs are recommended; Waco on the Bosque River, Proctor on the Leon River, Lampasas on the Lampasas River, Laneport on the San Gabriel River, Somerville on Yegua Creek and Ferguson on the Navasota River. These reservoirs will have a combined flood control storage capacity of 4,223,000 acre-feet. Their purpose is for flood control, conservation and power.

Channel improvements to decrease flood damage have been authorized on the Upper Leon River at Eastland and Mill Creek near Bellville, and recommended on Sulphur Creek at Lampasas. Many improvements have been constructed at Freeport and Velasco and others are being considered in the same area in the interest of navigation.

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1/ Report on Survey of Brazos River and Tributaries, Texas; Oyster Creek, Texas; Jones Creek, Texas. Department of the Army, Corps of Engineers, U. S. Engineers Office, Galveston, Texas. Unpublished.


Figure 6

**SOIL CONSERVATION DISTRICTS**
**BRAZOS RIVER WATERSHED - TEXAS**
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P MERRILL

REFERENCE Regional Technical Operations and State Conservationists
CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL
COMPILED P.E.M. TRACED F.I.O. CHECKED A.H.O. DATE 4-7-49

4-R-7245-3

There are numerous levee systems in the lower reaches of the Leon, Little and Brazos Rivers which have been constructed by private interests. The Corps of Engineers recommends construction and repair of levees to relieve flood damage in Burleson County.

Possum Kingdom reservoir is the only large reservoir in the watershed. This has a storage capacity of 733,800 acre-feet of which 547,500 acre-feet is used for electric power. This dam was constructed by the Brazos River Conservation and Reclamation District in 1942 at a cost of $8,677,000. This reservoir has a beneficial effect on flood damage potentialities for some distance downstream.

## IRRIGATION AND DRAINAGE

There are approximately 12 counties in the High Plains area in which there is extensive development of irrigation from shallow groundwaters. 1/ This irrigated area is predominately in the non-contributing area. The intensity of groundwater use is shown by the statistics from five counties which are almost entirely within the Brazos River Watershed. In 1940 there were over 2,600 farms with about 85,000 irrigated acres within these 5 counties. During and after the last war the acres under irrigation have increased very rapidly.

Rice culture under irrigation with water from the Brazos River is practiced within and adjacent to the watershed in Brazoria, Fort Bend, Galveston and Waller counties. Four companies have permits to appropriate about 240,000 acre-feet annually from the Brazos River for the irrigation of 120,000 acres. On the average about 197,000 acres are under canals and about 70,450 acres are irrigated. 2/

Other small irrigation projects for individual fields or farms are scattered throughout the watershed. Investigations are projected by the Bureau of Reclamation for several irrigation developments in the Little River and the Clear Fork and Double Mountain Fork of the Brazos River.

Six drainage districts have been organized and various improvements constructed in Fort Bend and Brazoria counties. 3/ Most of these districts are solvent and are maintaining their improvements but they are hampered by lack of adequate main outlets. Improvement or rehabilitation of the existing systems is necessary to secure full usage of the

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1/ Ground Water and Irrigation in the High Plains of Texas, USDA, Soil Conservation Service, Western Gulf Region, 1947.

2/ Report on Survey of Brazos River and Tributaries, Texas: Oyster, Creek, Texas; Jones Creek, Texas. Department of the Army, U. S. Corps of Engineers, Galveston, Texas, unpublished.

3/ Report of Drainage Surveys (1) Brazoria-Galveston Soil Conservation District, Texas, 1947 (2) Coastal Plains Soil Conservation District, Texas, 1947, Soil Conservation Service. Western Gulf Region.

land. In Fort Bend County there are over 463,000 acres feasible for drainage improvement while in Brazoria County there are 645,000. 1/ These figures include some areas outside of the Brazos River Watershed boundary.

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1/ Report on Reconnaissance Drainage Survey of Region 4, U. S. D. A., Soil Conservation Service, Western Gulf Region, 1948.

# APPENDIX III

## HYDROLOGY

### GENERAL METHODOLOGY

Reductions in runoff in the Brazos River Watershed resulting from the recommended program were determined through the procedures described on the following pages.

In order to study the headwater tributaries in relation to their contributing watersheds, eight sample tributary watersheds, averaging 122 square miles in drainage area were selected. These watersheds were considered representative of the conservation problem areas in which they are located. Among the characteristics considered were topography, soils, land use, precipitation, and type of flood plain. No runoff records were available for such headwater areas and a method was devised for estimating sample tributary runoff by applying rainfalls from selected precipitation gages and relating these values to the resulting stream flow. All storms producing damaging floods during the 15-year period, 1933-1947 were used. From this series, depths of runoff were computed for the present and future conditions which will prevail after installation of the recommended program. The reductions in runoff were determined from records made on experimental areas of similar cover and soil conditions. These methods used in the study of sample tributaries were also used for all tributaries not having records of stream flow measurements.

A relationship between surface runoff and the probable peak in stream flow was established from examination of highwater marks and by comparison with flows in similar streams. The area inundated was computed by depth increments and the corresponding value of flood plain damages was determined for each flood producing storm of the series. Separate computations were made to determine the areas inundated by each flood after installation of the recommended program.

The reductions in average annual damage on the flood plains of the main streams resulting from the recommended program were computed as described in the following. Where stream gage records were available the damage producing flood series was determined from the flood flows shown in the records. The depths of runoff from the contributing watershed were calculated for each damage producing flood and the reduced depths of runoff resulting from installation of the recommended program and annual damage and benefits were computed by the same method used for sample tributaries.

No damages or benefits were computed for that portion of the Brazos River flood plain below Possum Kingdom Reservoir except where damages were caused by floodwaters from certain tributary streams.

The probable effects on stream flow rates and volumes of the installation of the recommended program were considered. This consideration was prompted largely by the fact that during periods of low flow the discharge of the Brazos River is inadequate to meet irrigation needs.

Present knowledge provides no reliable means of computing with acceptable accuracy the change in total annual stream discharge to be expected on large watersheds as a result of the recommended measures. Many instances of observed increases in minimum stream flow have been reported, but quantitative experimental data are lacking. A study of the rock structures in the Grand Prairie, West Cross Timbers, Forested Coastal Plain and East Cross Timbers indicates that substantial additions will be made to shallow ground water aquifers, which would appear as increased low water flow.

In general, it may be assumed that the volume of stream discharge involved in the reduced peak of the flood hydrograph will be relatively small in the tributaries characterized by flash floods. Of the water removed from the peak of the flood hydrograph, a large portion will be infiltrated into the soil and move below the surface toward the stream beds. This sub-surface discharge may begin in small watersheds within a few hours after the period of infiltration and may continue in larger watersheds for a number of weeks. Geologic formation and soil characteristics are important factors governing the sub-surface flow and tend to complicate any attempt toward a complete hydrologic analysis of larger watersheds. It is believed, however, that the base flow in streams will be increased by the application of the recommended measures and that proportionally this increase will be greater during periods of critically low flow.

An estimate was made of the potential decrease in annual stream discharge due to evaporation from the permanent pools of the recommended floodwater retarding structures on the Brazos River Watershed. No allowance was made for seepage and the underground escape of water from the reservoirs. In some parts of the watershed seepage from the structures may result in an appreciable increase in the delayed return flow into streams, with accompanying benefits. The maximum probable loss from the structures during the period of June through August would be 28,800 acre-feet, based on the average evaporation of 21.4 inches at Temple. If runoff occurred on the watershed during this period with such distribution as to completely replenish the conservation pools of all the structures, the average total discharge of the Brazos River at Richmond for the 5 years of least flow would be reduced 8.9 percent. The average annual discharge at Richmond would be reduced 1.3 percent as a result of evaporation. Since rainfalls are not general on areas the size of the Brazos River Watershed during times of critical moisture deficiency, it is probable that the maximum reduction estimated will be experienced only at very infrequent intervals.

It is expected that the regulation of stream flow of the Brazos River by the flood control and power reservoirs which will be installed by the Corps of Engineers will overshadow the effects of the soil conservation practices and floodwater retarding structures and other measures recommended in this report.

## BASIC DATA

### Precipitation Records

Precipitation records were obtained from "Climatological Data" published by the U. S. Department of Commerce, Weather Bureau. The stations and their period of record are shown in figure 7, and their locations in figure 8. These stations have good records of five years or more during the period 1933-1947 and were in operation at the close of 1947. There have been about 200 additional stations with old, short or fragmentary periods of record operating in or near the Brazos River Watershed that are not shown in the figures mentioned.

Average annual precipitation was determined from Weather Bureau published records for 74 stations having long periods of operation (figure 9). The records published as of December 31, 1947 are based on average annual rainfall computed for the entire period of record through 1942 except for first-order Weather Bureau stations which are based on adopted normals. Figure 10 shows average annual monthly precipitation at four locations representing the range of climates found in the watershed.

### Stream Flow Records

Stream flow records used to establish the relationship between rainfall and runoff used in the analysis were obtained from water-supply papers published by the Geological Survey. The stream gaging stations in the Brazos River Watershed, and their period of operation are shown in figure 11. The locations of these stations are shown in figure 8. Reservoir level stations are included in the same figures. Stream discharge information for many of the stations is shown in table 15. Data from records published by the Geological Survey were used to compute the values of average annual runoff shown in the table.

### Flood Plain Data

Surveys were made in numerous sample and main tributary streams to find the relationship between stream channels and flood plains, and to determine stream gradients. These investigations included the surveying of 159 valley cross sections, along 773 miles of the streams as shown in figure 12. In addition 78 locations were surveyed to permit investigation of sites for small upstream floodwater retarding structures. Extensive use was made of aerial photographs in this phase of the survey.

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
H.H. BENNETT - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL CONSERVATOR

| NO. | STATIONS | COUNTY | LATITUDE | LONGITUDE |
|---|---|---|---|---|
| | * QUAY | QUAY | 34° 56' | 103° 48' |
| | * BELLVIEW (N.R.) | CURRY | 34° 56' | 103° 08' |
| | * CAMERON (N.R.) | QUAY | 34° 53' | 103° 24' |
| | * RAGLAND | QUAY | 34° 50' | 103° 46' |
| | * FORREST | QUAY | 34° 48' | 103° 37' |
| | * BROADVIEW (N.R.) | CURRY | 34° 44' | 103° 13' |
| | * HASSELL | QUAY | 34° 41' | 103° 59' |
| | DAVIS RANCH | CURRY | 34° 37' | 103° 09' |
| | CLOVIS No. 2 (N.R.) | CURRY | 34° 25' | 103° 14' |
| | CLOVIS No 3 (N.R.) | CURRY | 34° 21' | 103° 19' |
| | CLOVIS No. 1 (N.R.) | CURRY | 34° 29' | 103° 19' |
| | CLOVIS | CURRY | 34° 26' | 103° 13' |
| | MELROSE | CURRY | 34° 26' | 103° 41' |
| | FLOYD | ROOSEVELT | 34° 14' | 103° 33' |
| | PORTALES (EVP. STA.) | ROOSEVELT | 34° 13' | 103° 25' |
| | PORTALES | ROOSEVELT | 34° 11' | 103° 20' |
| | ELIDA | ROOSEVELT | 33° 59' | 103° 43' |
| | RICHLAND (N.R.) | ROOSEVELT | 33° 52' | 103° 27' |
| | VALLEY VIEW | ROOSEVELT | 33° 50' | 103° 43' |
| | * CROSSROADS | LEA | 33° 32' | 103° 21' |
| 1 | * GARCIA LAKE (N.R.) | DEAF SMITH | 34° 53' | 103° 02' |
| 2 | * DIMMITT (N.R.) | CASTRO | 34° 33' | 102° 12' |
| 3 | FARWELL | PARMER | 34° 23' | 102° 58' |
| 4 | MULESHOE No. 2 | BAILEY | 34° 14' | 102° 43' |
| 4 | MULESHOE | BAILEY | 34° 13' | 102° 43' |
| 5 | OLTON | LAMB | 34° 11' | 102° 08' |
| 6 | LITTLEFIELD | LAMB | 33° 56' | 102° 19' |
| 6 | LITTLEFIELD (N.R.) | LAMB | 33° 56' | 102° 20' |
| 7 | PETTIT (N.R.) | HOCKLEY | 33° 44' | 102° 28' |
| 8 | MORTON | COCHRAN | 33° 39' | 102° 48' |
| 9 | * MAPLE (N.R.) | COCHRAN | 33° 47' | 102° 54' |
| 10 | * PLAINS | YOAKUM | 33° 11' | 102° 50' |
| 11 | * BROWNFIELD | TERRY | 33° 11' | 102° 16' |
| 12 | * TULIA (N.R.) | SWISHER | 34° 35' | 101° 42' |
| 13 | * KRESS | SWISHER | 34° 22' | 101° 45' |
| 14 | * QUITAQUE | BRISCOE | 34° 23' | 101° 03' |
| 15 | PLAINVIEW | HALE | 34° 12' | 101° 42' |
| 16 | FLOYDADA | FLOYD | 33° 59' | 101° 19' |
| 17 | ABERNATHY | HALE | 33° 50' | 101° 50' |
| 18 | RALLS | CROSBY | 33° 40' | 101° 22' |
| 19 | CROSBYTON | CROSBY | 33° 39' | 101° 13' |
| 20 | LUBBOCK (N.R.) | LUBBOCK | 33° 35' | 101° 48' |
| 21 | LUBBOCK | LUBBOCK | 33° 35' | 101° 48' |
| 22 | POST | GARZA | 33° 12' | 101° 22' |
| 23 | * TAHOKA | LYNN | 33° 10' | 101° 47' |
| 24 | POLAR | KENT | 33° 01' | 101° 00' |
| 25 | * O'DONNELL | LYNN | 32° 58' | 101° 50' |
| 26 | * GAIL | BORDEN | 32° 46' | 101° 27' |
| 27 | * LAMESA (N.R.) | DAWSON | 32° 44' | 101° 56' |
| 28 | * KNAPP (N.R.) | BORDEN | 32° 36' | 101° 15' |
| 29 | * PADUCAH No. 2 | COTTLE | 34° 01' | 100° 18' |
| 30 | * PADUCAH (N.R.) | COTTLE | 34° 02' | 100° 20' |
| 31 | * MATADOR | MOTLEY | 34° 01' | 100° 49' |
| 32 | * GUTHRIE | KING | 33° 37' | 100° 18' |
| 33 | SPUR (N.R.) | DICKENS | 33° 29' | 100° 52' |


LEGEND

- (hatched bar) RECORDING STATION, PERIOD OF RECORD
- (solid bar) NON-RECORDING STATION, PERIOD OF RECORD
- * OUTSIDE OF WATERSHED
- (NR) NEAR
- AP AIRPORT
- ⊥ RECORDS AVAILABLE PRIOR TO 1885

NOTE:
UNNUMBERED STATIONS ARE LOCATED IN NEW MEXICO.
NUMBERS REFER TO LOCATIONS SHOWN ON FIGURE 8
STATIONS HAVING SHORT OR FRAGMENTARY RECORDS OR NO RECORD SINCE 1933 NOT SHOWN.
SOURCE OF DATA:
1943-1947 U.S. WEATHER BUREAU. PRIOR TO 1943
U.S. CORPS OF ENGINEERS UNPUBLISHED DATA.

Figure 7

PRECIPITATION STATIONS
SHOWING PERIOD OF RECORD

BRAZOS RIVER WATERSHED - TEXAS

Sheet 1 of 4

4-R-7245-24

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
H.H. BENNETT - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL CONSERVATOR

| NO. | STATIONS | COUNTY | LATITUDE | LONGITUDE |
|---|---|---|---|---|
| 34 | JAYTON | KENT | 33° 15' | 100° 34' |
| 35 | ASPERMONT | STONEWALL | 33° 09' | 100° 13' |
| 36 | HAMLIN | JONES | 32° 53' | 100° 07' |
| 37 | ROTAN | FISHER | 32° 51' | 100° 28' |
| 38 | ROBY | FISHER | 32° 45' | 100° 23' |
| 39 | * SNYDER | SCURRY | 32° 44' | 100° 55' |
| 40 | TRENT (N.R.) | TAYLOR | 32° 29' | 100° 06' |
| 41 | ROSCOE | NOLAN | 32° 27' | 100° 32' |
| 42 | * COLORADO CITY | MITCHELL | 32° 24' | 100° 51' |
| 43 | * LORAINE (N.R.) | MITCHELL | 32° 25' | 100° 42' |
| 44 | * SILVER | COKE | 32° 02' | 100° 44' |
| 45 | * ROBERT LEE | COKE | 31° 52' | 100° 30' |
| 46 | * CROWELL | FOARD | 34° 00' | 99° 42' |
| 47 | * TRUSCOTT | KNOX | 33° 45' | 99° 48' |
| 48 | BENJAMIN | KNOX | 33° 34' | 99° 47' |
| 49 | SEYMOUR | BAYLOR | 33° 35' | 99° 16' |
| 50 | RENDHAM (N.R.) | BAYLOR | 33° 34' | 99° 09' |
| 51 | MUNDAY No. 2. | KNOX | 33° 23' | 99° 39' |
| 52 | MUNDAY | KNOX | 33° 27' | 99° 38' |
| 53 | RED SPRINGS (N.R.) | BAYLOR | 33° 36' | 99° 23' |
| 54 | KNOX CITY | KNOX | 33° 25' | 99° 48' |
| 55 | HASKELL (N.R.) SCS-5 | HASKELL | 33° 04' | 99° 37' |
| 56 | HASKELL (N.R.) | HASKELL | 33° 14' | 99° 48' |
| 57 | HASKELL | HASKELL | 33° 11' | 99° 44' |
| 58 | THROCKMORTON | THROCKMORTON | 33° 10' | 99° 13' |
| 59 | WOODSON (N.R.) | THROCKMORTON | 33° 04' | 99° 01' |
| 60 | STAMFORD (N.R.) | JONES | 32° 56' | 99° 49' |
| 61 | STAMFORD | JONES | 32° 57' | 99° 48' |
| 62 | ALBANY | SHACKLEFORD | 32° 44' | 99° 18' |
| 63 | NUGENT (N.R.) | JONES | 32° 43' | 99° 43' |
| 64 | TRUBY (N.R.) | JONES | 32° 38' | 99° 56' |
| 65 | ABILENE (A.P.) | TAYLOR | 32° 26' | 99° 41' |
| 66 | ABILENE | TAYLOR | 32° 27' | 99° 44' |
| 67 | PUTNAM | CALLAHAN | 32° 22' | 99° 12' |
| 68 | * McDONALD STORE | CALLAHAN | 32° 12' | 99° 24' |
| 69 | * LAWN | TAYLOR | 32° 08' | 99° 44' |
| 70 | * CROSS PLAINS (N.R.) | CALLAHAN | 32° 08' | 99° 09' |
| 71 | * CROSS PLAINS | CALLAHAN | 32° 07' | 99° 11' |
| 72 | * WINTERS | RUNNELS | 31° 58' | 99° 59' |
| 73 | * BYRDS | BROWN | 31° 56' | 99° 02' |
| 74 | * COLEMAN | COLEMAN | 31° 50' | 99° 26' |
| 75 | * BALLINGER | RUNNELS | 31° 46' | 99° 57' |
| 76 | * DUNDEE (N.R.) | ARCHER | 33° 45' | 98° 59' |
| 77 | * ARCHER CITY | ARCHER | 33° 36' | 98° 37' |
| 78 | * ANTELOPE | JACK | 33° 26' | 98° 22' |
| 79 | OLNEY | YOUNG | 33° 26' | 98° 47' |
| 80 | * JACKSBORO (MISC.) | JACK | 33° 12' | 98° 10' |
| 80 | * JACKSBORO | JACK | 33° 13' | 98° 10' |
| 81 | GRAHAM | YOUNG | 33° 06' | 98° 35' |
| 82 | POSSUM KINGDOM DAM | PALO PINTO | 32° 52' | 98° 26' |
| 83 | MINERAL WELLS | PALO PINTO | 32° 48' | 98° 10' |
| 84 | BRECKENRIDGE | STEPHENS | 32° 46' | 98° 53' |
| 85 | HARPERSVILLE (A.P.) | STEPHENS | 32° 37' | 98° 54' |
| 86 | THURBER | ERATH | 32° 30' | 98° 25' |
| 87 | RANGER (N.R.) | EASTLAND | 32° 29' | 98° 37' |


LEGEND

- RECORDING STATION, PERIOD OF RECORD.
- NON-RECORDING STATION, PERIOD OF RECORD
- * OUTSIDE OF WATERSHED
- (NR.) NEAR
- (AP.) AIRPORT
- ┘ RECORDS AVAILABLE PRIOR TO 1885

NOTE:
NUMBERS REFER TO LOCATIONS SHOWN ON FIGURE 8
STATIONS HAVING SHORT OR FRAGMENTARY RECORDS OR NO RECORD SINCE 1933 NOT SHOWN.
SOURCE OF DATA:
1943-1947 U.S. WEATHER BUREAU PRIOR TO 1943
U.S. CORPS OF ENGINEERS UNPUBLISHED DATA.

Figure 7

PRECIPITATION STATIONS
SHOWING PERIOD OF RECORD

BRAZOS RIVER WATERSHED - TEXAS

Sheet 2 of 4

4-R-7245-24

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL CONSERVATOR

| NO. | STATIONS | COUNTY | LATITUDE | LONGITUDE |
|---|---|---|---|---|
| 88 | EASTLAND | EASTLAND | 32° 24' | 98° 49' |
| 89 | STEPHENVILLE | ERATH | 32° 15' | 98° 13' |
| 90 | STEPHENVILLE (NR.) | ERATH | 32° 10' | 98° 18' |
| 91 | RISING STAR | EASTLAND | 32° 06' | 98° 58' |
| 92 | DUBLIN | ERATH | 32° 05' | 98° 20' |
| 93 | HICO | HAMILTON | 31° 59' | 98° 02' |
| 94 | COMANCHE | COMANCHE | 31° 54' | 98° 36' |
| 95 | * BLANKET | BROWN | 31° 49' | 98° 46' |
| 96 | * BROWNWOOD | BROWN | 31° 43' | 98° 59' |
| 97 | HAMILTON | HAMILTON | 31° 42' | 98° 08' |
| 98 | INDIAN GAP | HAMILTON | 31° 40' | 98° 25' |
| 99 | * MULLIN | MILLS | 31° 33' | 98° 40' |
| 100 | EVANT (NR.) | CORYELL | 31° 29' | 98° 04' |
| 101 | * GOLDTHWAITE | MILLS | 31° 27' | 98° 34' |
| 102 | MOLINE | LAMPASAS | 31° 23' | 98° 18' |
| 103 | * LOMETA | LAMPASAS | 31° 13' | 98° 24' |
| 104 | * SAN SABA | SAN SABA | 31° 11' | 98° 44' |
| 105 | NIX STORE | LAMPASAS | 31° 04' | 98° 22' |
| 106 | LAMPASAS | LAMPASAS | 31° 04' | 98° 11' |
| 107 | LAKE VICTOR | BURNET | 30° 54' | 98° 11' |
| 108 | * LLANO | LLANO | 30° 46' | 98° 40' |
| 109 | * BURNET | BURNET | 30° 45' | 98° 14' |
| 110 | * FAIRLAND | BURNET | 30° 39' | 98° 18' |
| 111 | * LAKE BRIDGEPORT DAM | WISE | 33° 13' | 97° 50' |
| 112 | * BRIDGEPORT | WISE | 33° 13' | 97° 46' |
| 113 | * WEATHERFORD | PARKER | 32° 46' | 97° 48' |
| 114 | GRANBURY | HOOD | 32° 26' | 97° 48' |
| 115 | * ALVARADO | JOHNSON | 32° 25' | 97° 13' |
| 116 | CLEBURNE | JOHNSON | 32° 21' | 97° 24' |
| 117 | RAINBOW | SOMERVELL | 32° 15' | 97° 42' |
| 118 | ITASCA | HILL | 32° 10' | 97° 09' |
| 119 | KOPPERL | BOSQUE | 32° 04' | 97° 30' |
| 120 | HILLSBORO | HILL | 32° 01' | 97° 08' |
| 121 | CRANFILLS GAP | BOSQUE | 31° 46' | 97° 50' |
| 122 | CLIFTON (NR.) | BOSQUE | 31° 46' | 97° 27' |
| 123 | ROSS (NR.) | McLENNAN | 31° 44' | 97° 07' |
| 124 | WACO (RIVER) | McLENNAN | 31° 34' | 97° 08' |
| 125 | WACO (AP.) | McLENNAN | 31° 37' | 97° 13' |
| 126 | WACO | McLENNAN | 31° 35' | 97° 10' |
| 127 | CORYELL CITY | CORYELL | 31° 33' | 97° 37' |
| 128 | GATESVILLE | CORYELL | 31° 26' | 97° 45' |
| 129 | McGREGOR | McLENNAN | 31° 26' | 97° 25' |
| 130 | HEWITT | McLENNAN | 31° 26' | 97° 12' |
| 131 | TROY | BELL | 31° 12' | 97° 18' |
| 132 | COPPERAS COVE | CORYELL | 31° 08' | 97° 54' |
| 133 | KILLEEN | BELL | 31° 07' | 97° 43' |
| 134 | TEMPLE (NR) EXP. STA. A. | BELL | 31° 03' | 97° 21' |
| 134 | TEMPLE STATE EXP. STA. | BELL | 31° 03' | 97° 21' |
| 135 | TEMPLE | BELL | 31° 05' | 97° 22' |
| 136 | BURLINGTON (NR) | MILAM | 31° 00' | 97° 01' |
| 137 | BRIGGS | BURNET | 30° 53' | 97° 55' |
| 138 | JARRELL | WILLIAMSON | 30° 49' | 97° 36' |
| 139 | DAVILLA | MILAM | 30° 47' | 97° 16' |
| 140 | LIBERTY HILL | WILLIAMSON | 30° 40' | 97° 56' |
| 141 | TAYLOR | WILLIAMSON | 30° 34' | 97° 24' |


LEGEND

RECORDING STATION, PERIOD OF RECORD.
NON-RECORDING STATION, PERIOD OF RECORD
* OUTSIDE OF WATERSHED
(NR) NEAR
(AP) AIRPORT
RECORDS AVAILABLE PRIOR TO 1885

NOTE:
NUMBERS REFER TO LOCATIONS SHOWN ON FIGURE 8
STATIONS HAVING SHORT OR FRAGMENTARY RECORDS OR NO RECORD SINCE 1933 NOT SHOWN.
SOURCE OF DATA:
1943-1947 U.S. WEATHER BUREAU PRIOR TO 1943
U.S. CORPS OF ENGINEERS UNPUBLISHED DATA.

Figure 7

PRECIPITATION STATIONS
SHOWING PERIOD OF RECORD

BRAZOS RIVER WATERSHED - TEXAS

Sheet 3 of 4

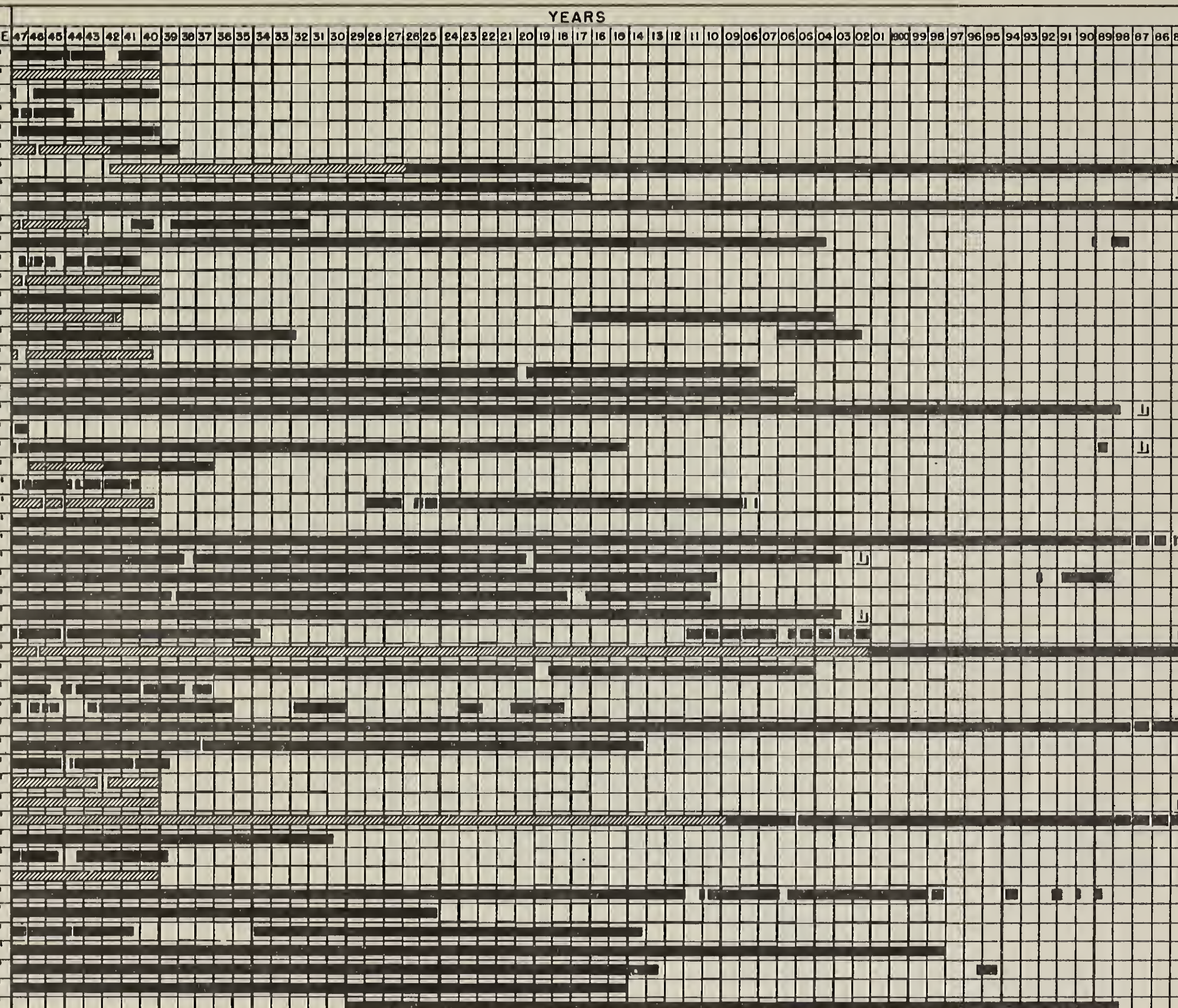
4-R-7245-24

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL CONSERVATOR

| NO. | STATIONS | COUNTY | LATITUDE | LONGITUDE |
|---|---|---|---|---|
| 142 | * PFLUGERVILLE | TRAVIS | 30° 26' | 97° 37' |
| 143 | LEXINGTON | LEE | 30° 25' | 97° 01' |
| 144 | * MANSFIELD DAM | TRAVIS | 30° 22' | 97° 55' |
| 145 | * AUSTIN (RIVER) | TRAVIS | 30° 15' | 97° 41' |
| 146 | * AUSTIN (DAM) | TRAVIS | 30° 16' | 97° 47' |
| 147 | * AUSTIN (AP) | TRAVIS | 30° 18' | 97° 42' |
| 148 | * AUSTIN (CITY) | TRAVIS | 30° 16' | 97° 44' |
| 149 | * SMITHVILLE | BASTROP | 30° 01' | 97° 09' |
| 150 | * CORSICANA | NAVARRO | 32° 05' | 96° 28' |
| 151 | * DAWSON | NAVARRO | 31° 54' | 96° 43' |
| 152 | MEXIA | LIMESTONE | 31° 41' | 96° 29' |
| 153 | * FAIRFIELD | FREESTONE | 31° 41' | 96° 07' |
| 154 | RIESEL (NR) SCS 69 | FALLS | 31° 29' | 96° 53' |
| 155 | * BUFFALO | LEON | 31° 28' | 96° 04' |
| 156 | JEWETT | LEON | 31° 21' | 96° 09' |
| 157 | MARLIN | FALLS | 31° 18' | 96° 54' |
| 158 | WHEELOCK (NR) | BRAZOS | 30° 52' | 96° 22' |
| 159 | CAMERON | MILAM | 30° 51' | 96° 59' |
| 160 | VALLEY JUNCTION | ROBERTSON | 30° 50' | 96° 39' |
| 161 | COLLEGE STATION | BRAZOS | 30° 37' | 96° 22' |
| 162 | NAVASOTA (NR) | GRIMES | 30° 23' | 96° 07' |
| 162 | NAVASOTA | GRIMES | 30° 23' | 96° 06' |
| 163 | NAVASOTA (AP) | GRIMES | 30° 25' | 96° 03' |
| 164 | DIME BOX | LEE | 30° 21' | 96° 48' |
| 165 | SOMERVILLE | BURLESON | 30° 21' | 96° 31' |
| 166 | * GIDDINGS | LEE | 30° 11' | 96° 56' |
| 167 | BRENHAM | WASHINGTON | 30° 10' | 96° 24' |
| 168 | HEMPSTEAD | WALLER | 30° 07' | 96° 10' |
| 169 | * LA GRANGE | FAYETTE | 29° 55' | 96° 53' |
| 170 | SEALY | AUSTIN | 29° 47' | 96° 09' |
| 171 | * COLUMBUS | COLORADO | 29° 42' | 96° 33' |
| 172 | * WHARTON | WHARTON | 29° 20' | 96° 07' |
| 173 | * PALESTINE | ANDERSON | 31° 46' | 95° 38' |
| 174 | * LONG LAKE | ANDERSON | 31° 38' | 95° 47' |
| 175 | * CENTERVILLE | LEON | 31° 15' | 95° 58' |
| 176 | * MADISONVILLE | MADISON | 30° 57' | 95° 54' |
| 177 | * HUNTSVILLE | WALKER | 30° 44' | 95° 34' |
| 178 | ANDERSON | GRIMES | 30° 28' | 95° 59' |
| 179 | * PATTISON (NR) | WALLER | 29° 53' | 95° 49' |
| 180 | * KATY | HARRIS | 29° 47' | 95° 49' |
| 181 | * HOUSTON (CITY) | HARRIS | 29° 46' | 95° 22' |
| 181 | * HOUSTON | HARRIS | 29° 46' | 95° 21' |
| 182 | * HOUSTON (AP) | HARRIS | 29° 39' | 95° 17' |
| 183 | * GASTON | FORT BEND | 29° 43' | 95° 44' |
| 184 | * ALIEF (NR) | HARRIS | 29° 43' | 95° 36' |
| 185 | SUGARLANO | FORT BEND | 29° 36' | 95° 38' |
| 186 | RICHMOND | FORT BEND | 29° 35' | 95° 45' |
| 187 | ROSENBERG | FORT BEND | 29° 34' | 95° 48' |
| 188 | * ALVIN | BRAZORIA | 29° 26' | 95° 14' |
| 189 | * ANGLETON | BRAZORIA | 29° 12' | 95° 22' |
| 190 | * FREEPORT | BRAZORIA | 28° 57' | 95° 21' |
| 191 | BRAZORIA | BRAZORIA | 29° 03' | 95° 34' |




LEGEND

- RECORDING STATION, PERIOD OF RECORD
- NON-RECORDING STATION, PERIOD OF RECORD
- * OUTSIDE OF WATERSHED
- (NR) NEAR
- (AP) AIRPORT
- ┘ RECORDS AVAILABLE PRIOR TO 1885

NOTE

NUMBERS REFER TO LOCATIONS SHOWN ON FIGURE 8
STATIONS HAVING SHORT OR FRAGMENTARY RECORDS OR NO RECORD SINCE 1933 NOT SHOWN.
SOURCE OF DATA:
1943-1947 U.S. WEATHER BUREAU PRIOR TO 1943
U.S. CORPS OF ENGINEERS UNPUBLISHED DATA.

Figure 7

PRECIPITATION STATIONS
SHOWING PERIOD OF RECORD

BRAZOS RIVER WATERSHED-TEXAS

Sheet 4 of 4 4-R-7245-24

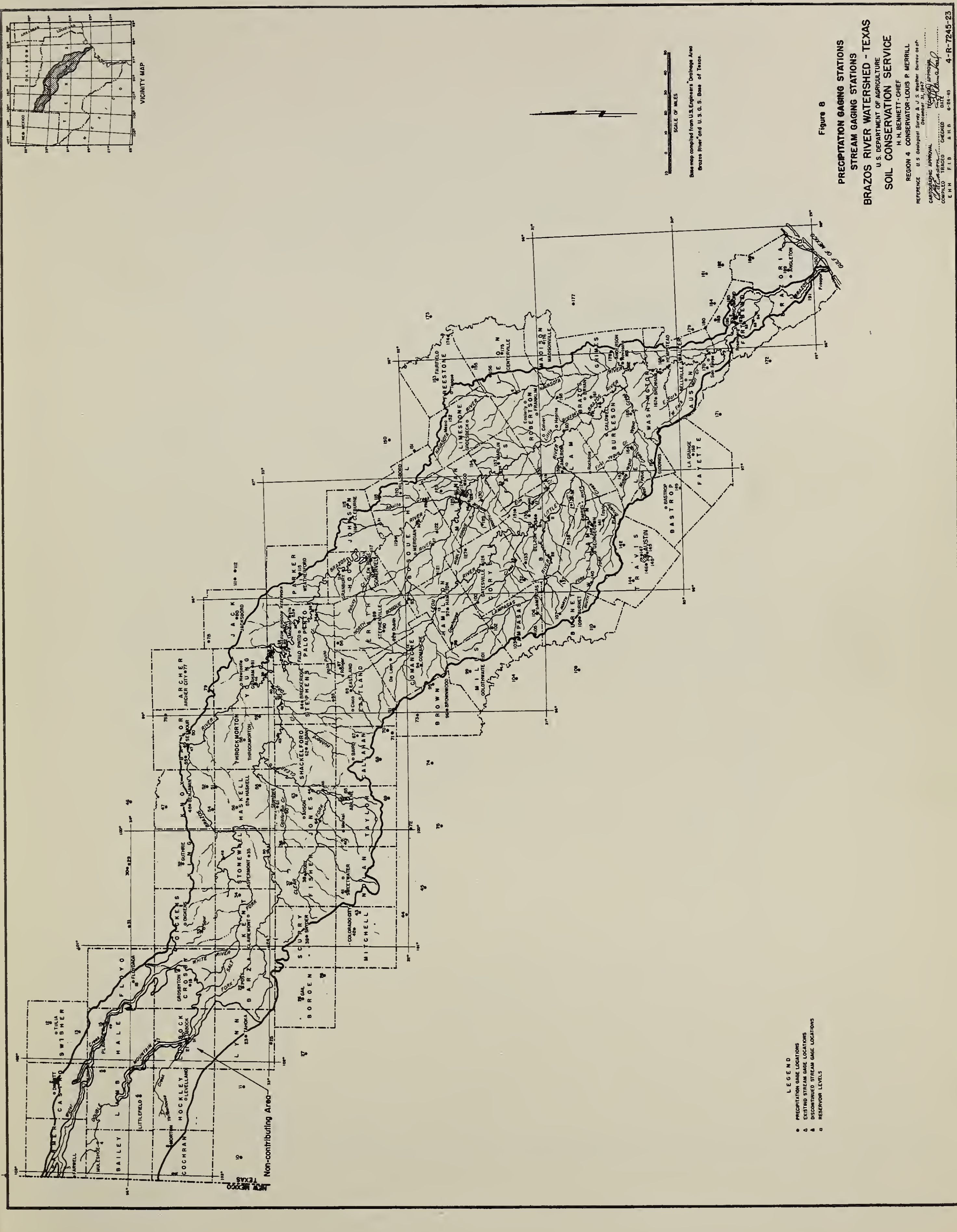
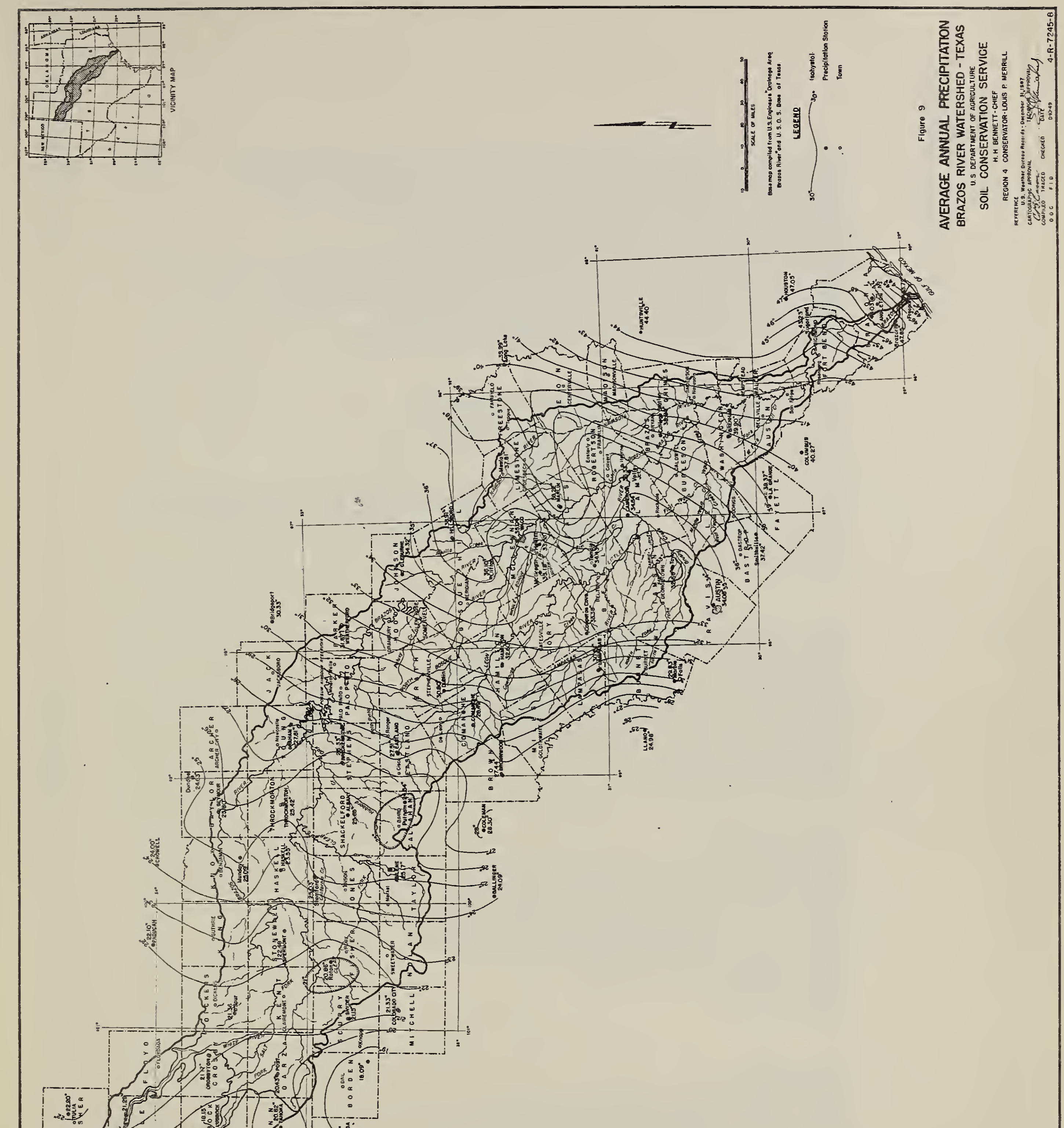


Figure 8
PRECIPITATION GAGING STATIONS
STREAM GAGING STATIONS
BRAZOS RIVER WATERSHED - TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P. MERRILL
REFERENCE U.S. Geological Survey & U.S. Weather Bureau as of December 31, 1947
CARTOGRAPHIC APPROVAL
TECHNICAL APPROVAL
COMPILED TRACED CHECKED DATE
E H H F L D A H B 6-24-49
4-R-7245-23
VICINITY MAP
SCALE OF MILES
Base map compiled from U.S. Engineers "Drainage Area Brazos River" and U.S.G.S. Base of Texas.
LEGEND
PRECIPITATION GAGE LOCATIONS
EXISTING STREAM GAGE LOCATIONS
DISCONTINUED STREAM GAGE LOCATIONS
RESERVOIR LEVELS
Non-contributing Area
NEW MEXICO
TEXAS
GULF OF MEXICO


VICINITY MAP
SCALE OF MILES
10 0 10 20 30 40 50
Base map compiled from U.S. Engineers' "Drainage Area Brazos River" and U.S.G.S. Base of Texas
LEGEND
30" 30" Isohyetal
Precipitation Station
Town
Figure 9
AVERAGE ANNUAL PRECIPITATION
BRAZOS RIVER WATERSHED - TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P. MERRILL
REFERENCE
U.S. Weather Bureau Records - December 31, 1937
CARTOGRAPHIC APPROVAL
TECHNICAL APPROVAL
COMPILED TRACED CHECKED DATE
4-R-7245-8
Non-contributing Area
NEW MEXICO
TEXAS
GULF OF MEXICO

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
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WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL CONSERVATOR

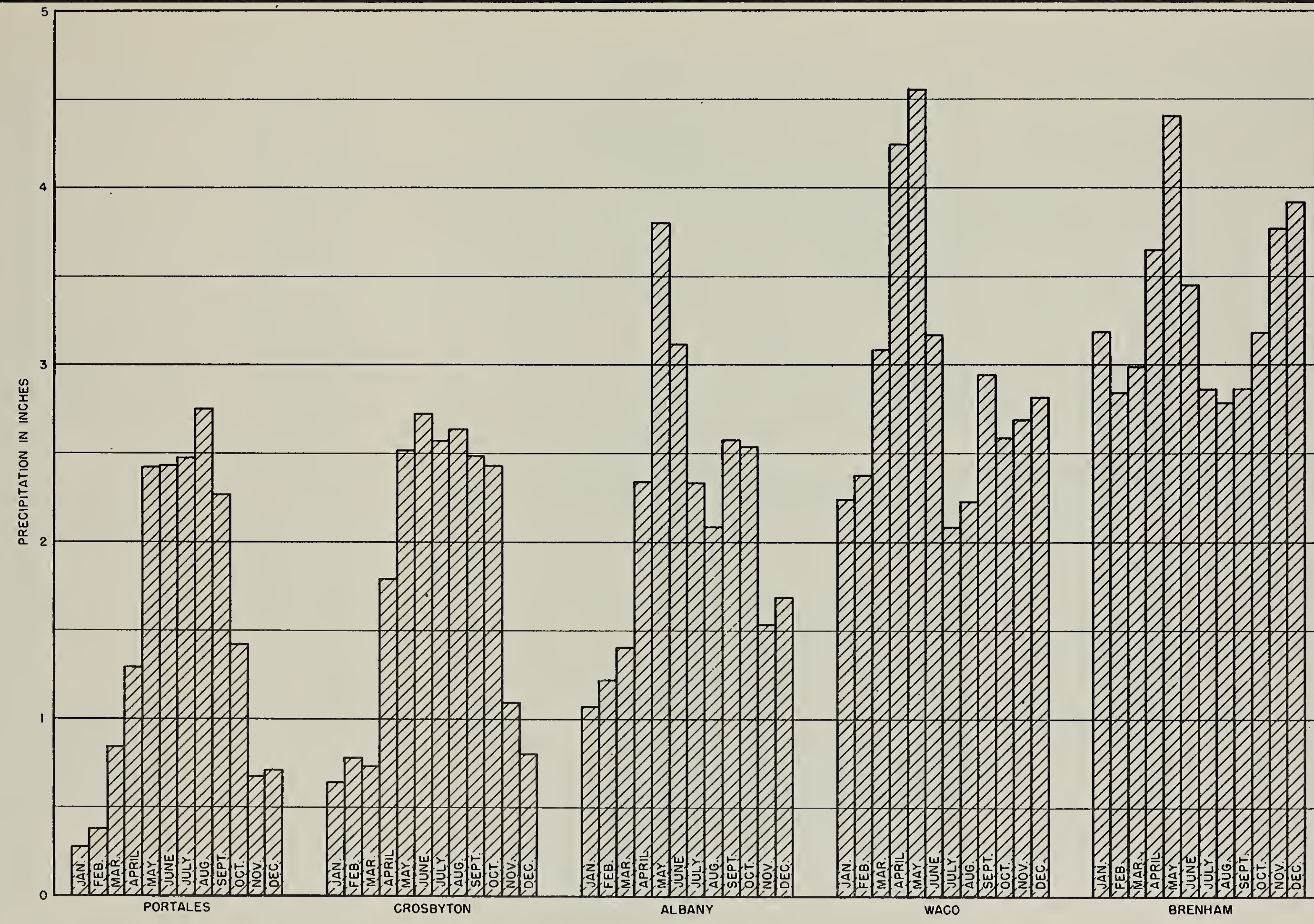


Figure 10
AVERAGE MONTHLY PRECIPITATION
BRAZOS RIVER WATERSHED - TEXAS

Source Data: U. S. Weather Bureau Records of December 31, 1947

F. I. B. 6-16-49 4-L-7245-22

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
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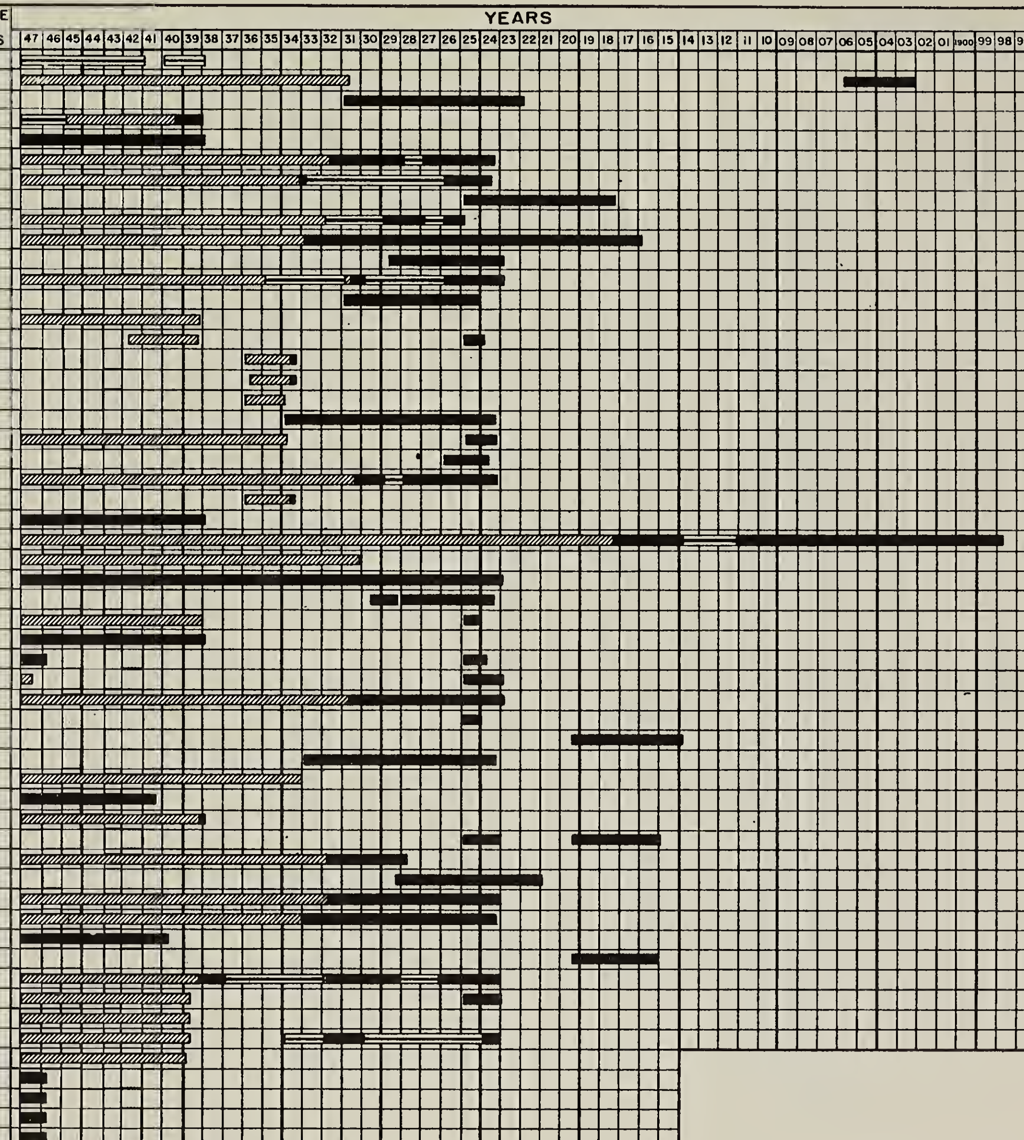
WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL CONSERVATOR

| STREAM | STATION | GAGE NO. | DRAINAGE AREA SQ. MILES |
|---|---|---|---|
| BRAZOS RIVER | AT EAST COLUMBIA | 1 | 35628 |
| BRAZOS RIVER | AT RICHMOND | 2 | 35163 |
| BRAZOS RIVER | AT ROSENBERG | 3 | 35135 |
| BRAZOS RIVER | NEAR SAN FELIPE | 4 | 34890 |
| BRAZOS RIVER | NEAR HEMPSTEAD | 5 | 34110 |
| NAVASOTA RIVER | NEAR EASTERLY | 6 | 925 |
| YEGUA RIVER | NEAR SOMERVILLE | 7 | 1016 |
| BRAZOS RIVER | NEAR COLLEGE STATION | 8 | 29852 |
| BRAZOS RIVER | NEAR BRYAN | 9 | 29784 |
| LITTLE RIVER | AT CAMERON | 10 | 6872 |
| LITTLE RIVER | NEAR LITTLE RIVER | 11 | 5097 |
| LEON RIVER | NEAR BELTON | 12 | 3422 |
| LEON RIVER | NEAR HAMILTON | 13 | 1840 |
| LEON RIVER | NEAR HASSE | 14 | 1228 |
| COWHOUSE CREEK | NEAR KILLEEN | 15 | 644 |
| BIG ELM CREEK | NEAR BUCKHOLTS | 16 | 155 |
| BIG ELM CREEK | NEAR TEMPLE | 17 | 70 |
| NORTH ELM CREEK | NEAR BEN ARNOLD | 18 | 33 |
| SAN GABRIEL RIVER | AT CIRCLEVILLE | 19 | 589 |
| SAN GABRIEL RIVER | AT GEORGETOWN | 20 | 390 |
| BRUSHY CREEK | AT COUPLAND | 21 | 192 |
| LAMPASAS RIVER | AT YOUNGSPORT | 22 | 1245 |
| DEER CREEK | AT CHILTON | 23 | 72 |
| BRAZOS RIVER | NEAR MARLIN | 24 | 20706 |
| BRAZOS RIVER | AT WACO | 25 | 20029 |
| BOSQUE RIVER | AT LAKE WACO (R.L.) 1 | 26 | 1666 |
| NORTH BOSQUE RIVER | NEAR CLIFTON | 27 | 1015 |
| SOUTH BOSQUE RIVER | NEAR SPEEGLEVILLE | 28 | 380 |
| AQUILLA CREEK | NEAR AQUILLA | 29 | 308 |
| BRAZOS RIVER | NEAR WHITNEY | 30 | 17597 |
| NOLANDS RIVER | AT BLUM | 31 | 291 |
| PALUXY CREEK | AT GLEN ROSE | 32 | 424 |
| BRAZOS RIVER | NEAR GLEN ROSE | 33 | 16297 |
| PALO PINTO CREEK | NEAR SANTO | 34 | 567 |
| BRAZOS RIVER | AT BRAZOS | 35 | 14787 |
| BRAZOS RIVER | NEAR MINERAL WELLS | 36 | 14670 |
| BRAZOS RIVER | NEAR PALO PINTO | 37 | 14312 |
| BRAZOS RIVER | NEAR GRAFORD (R.L.) 2 | 38 | 14098 |
| BRAZOS RIVER | NEAR SOUTH BEND | 39 | 13013 |
| CLEAR FORK OF BRAZOS RIVER | NEAR ELIASVILLE | 40 | 5705 |
| CLEAR FORK OF BRAZOS RIVER | NEAR CRYSTALL FALLS | 41 | 5622 |
| CLEAR FORK OF BRAZOS RIVER | AT CRYSTALL FALLS | 42 | 4334 |
| CLEAR FORK OF BRAZOS RIVER | AT FORT GRIFFIN | 43 | 3978 |
| CLEAR FORK OF BRAZOS RIVER | AT NUGENT | 44 | 2203 |
| ELM CREEK | NEAR NUGENT (R.L.) 3 | 45 | 482 |
| BRAZOS RIVER | NEAR GRAHAM | 46 | 7180 |
| BRAZOS RIVER | AT SEYMOUR | 47 | 5918 |
| SALT FORK OF BRAZOS RIVER | NEAR ASPERMONT | 48 | 2404 |
| WHITE RIVER | AT PLAINVIEW | 49 | 280 |
| DOUBLE MOUNTAIN FORK OF BRAZOS RIVER | NEAR ASPERMONT | 50 | 1855 |
| DOUBLE MOUNTAIN FORK OF BRAZOS RIVER | AT LUBBOCK | 51 | 78 |
| DRY CREEK | NEAR RICHMOND | 52 | 10 |
| BIG CREEK | NEAR NEEDVILLE | 53 | 38 |
| BIG CREEK | NEAR GUY | 54 | 112 |
| FAIRCHILD CREEK | NEAR NEEDVILLE | 55 | 25 |




LEGEND

- U.S.G.S. NON-RECORDING GAGE RECORD
- U.S.G.S. RECORDING GAGE RECORD
- U.S.G.S. GAGE HEIGHT, MONTHLY OR FRAGMENTARY RECORD
- (RL) RESERVOIR LEVELS
- 1 CITY OF WACO RECORDS
- 2 POSSUM KINGDOM RESERVOIR
- 3 FORT PHANTOM HILL RESERVOIR

NOTE:
GAGE NUMBERS INDICATE LOCATIONS SHOWN ON FIGURE B
DRAINAGE AREAS INCLUDE THE CONTRIBUTING WATERSHED ONLY AND ARE FROM UNPUBLISHED DATA COMPILED BY THE DEPT. OF THE ARMY, CORPS. OF ENGINEERS.
SOURCE OF DATA U.S.G.S. OR AS SHOWN AS OF DEC. 31, 1949

Figure 11

STREAM GAGING STATIONS
SHOWING PERIOD OF RECORD
BRAZOS RIVER WATERSHED - TEXAS

4-R-7245-10

Table 15. Annual Runoff and Maximum and Minimum Discharges at Various Locations
Brazos River Watershed

| No. 1/ | Stream | Location | Drainage Area 2/ | Average Discharge 3/ | Average Runoff | Annual 4/ | Maximum Discharge 3/ | Minimum Discharge 3/ |
|---|---|---|---|---|---|---|---|---|
| | | | (sq. mi.) | (second ft.) | (inches) | (ac.ft.) | (second ft.) | (second ft.) |
| 1 | Brazos River | At. E. Columbia | 35,628 | - | - | - | - | 1.54 |
| 2 | Brazos River | At Richmond | 35,163 | 8,269 | 3.19 | 5,986 | 117,000 | 33.0 |
| 4 | Brazos River | Nr. San Felipe | 34,890 | - | - | - | 152,000 | 278.0 |
| 5 | Brazos River | Nr. Hempstead | 34,110 | - | - | - | 116,000 | 254.0 |
| 6 | Navasota River | Nr. Easterly | 930 | 452 | 6.59 | 327 | 60,300 | 0 |
| 7 | Yegua Creek | Nr. Somerville | 1,016 | 326 | 4.36 | 236 | 56,800 | 0 |
| 9 | Brazos River | Nr. Bryan | 29,784 | 6,243 | 2.85 | 4,520 | - | 87.0 |
| 10 | Little River | At Cameron | 6,872 | 2,058 | 4.07 | 1,490 | 647,000 | 2.6 |
| 12 | Leon River | Nr. Belton | 3,422 | 773 | 3.07 | 560 | 45,000 | 0 |
| 14 | Leon River | Nr. Hasse | 1,228 | - | - | - | 8,740 | 0 |
| 20 | San Gabriel R. | At Georgetown | 390 | 194 | 6.73 | 140 | 37,500 | 0.2 |
| 22 | Lampasas River | At Youngsport | 1,245 | 340 | 3.70 | 246 | 53,200 | 0 |
| 24 | Brazos River | Nr. Marlin | 20,706 | - | - | - | 132,000 | 0 |
| 25 | Brazos River | At Waco | 20,029 | 2,750 | 1.86 | 1,991 | 246,000 | 0 |
| 27 | N. Bosque River | Nr. Clifton | 1,015 | 237 | 3.18 | 172 | 39,000 | 0 |
| 28 | S. Bosque River | Nr. Speegleville | 380 | - | - | - | 54,500 | 0 |
| 29 | Aquilla Creek | Nr. Aquilla | 308 | - | - | - | - | 0 |
| 30 | Brazos River | Nr. Whitney | 17,597 | - | - | - | 66,400 | 2.0 |
| 33 | Brazos River | Nr. Glenrose | 16,297 | 1,711 | 1.43 | 1,239 | 97,600 | 0 |
| 37 | Brazos River | Nr. Palo Pinto | 14,312 | 1,313 | 1.25 | 951 | 64,900 | 0 |
| 39 | Brazos River | Nr. South Bend | 13,013 | - | - | - | 87,400 | 0 |
| 40 | Clear Fork | Nr. Eliasville | 5,705 | - | - | - | 13,600 | 0 |
| 41 | Clear Fork | Nr. Crystall Falls | 5,658 | 505 | 1.21 | 366 | 35,800 | 0 |
| 43 | Clear Fork | At. Fort Griffin | 3,978 | 295 | 1.01 | 214 | 33,600 | 0 |
| 44 | Clear Fork | At Nugent | 2,203 | 163 | 1.00 | 118 | 47,000 | 0 |
| 47 | Brazos River | At Seymour | 5,918 | 472 | 1.08 | 342 | 95,400 | 0 |
| 48 | Salt Fork | Nr. Aspermont | 2,404 | - | - | - | 26,600 | 0 |
| 49 | White River | At Plainview | 280 | - | - | - | 12,000 | 0 |
| 50 | Dble.Mtn.Fork | Nr. Aspermont | 1,855 | 181 | 1.32 | 131 | 52,000 | 0 |
| 51 | Dble.Mtn.Fork | At Lubbock | 78 | - | - | - | 892 | 0 |

1/ Refers to location numbers shown on location map, figure 8.
2/ Contributing drainage area adjusted by Dept. of the Army, U. S. E. D.
3/ Published in Geological Survey Water-Supply Paper No. 1038
4/ Thousand acre-feet, add 000.
\- Not determined.


Figure 12

LOCATION OF WATERSHED INVESTIGATIONS
BRAZOS RIVER WATERSHED - TEXAS

Infiltration and Runoff Data

Reductions in runoff were determined from analysis of research results from the soil conservation experiment stations near Tyler and Temple, Texas, and from the experimental hydrologic watersheds near Waco and Garland, Texas. These data were collected and correlated by the Hydrologic Plans Section of the Soil Conservation Service. They were used to develop curves showing the reduction in runoff to be expected from the installation of land treatment or conservation measures on a watershed. The basic relationships of precipitation and runoff were determined from the stream gages in tributaries most nearly representative of areas to be studied. The effects of season, average daily rainfall intensities and antecedent rainfall on runoff were evaluated and were used in applying the relationships developed to the damage producing storm series.

## CALCULATION OF FLOOD REDUCTIONS

Rainfall-Runoff Relationship

The relationship between rainfall and runoff was determined in the following manner. Total rainfall was computed on the contributing watershed using the Thiessen Weighting method and this amount was plotted opposite the computed runoff. In tributaries having usable stream flow records, the depth of runoff on the contributing drainage area was calculated by converting the areas under the hydrographs of stream rises caused by typical storms. These values representing runoff were plotted opposite the precipitation causing the runoff, as referred to in the foregoing. The selection of typical storms was made to reflect the varying conditions of amount, duration, intensity and distributation of rainfall and the proximity of preceding storms. It was noted that the plotted points usually fell in one of two groups. The first group, designated as high runoff producing storms, was comprised of storms having either a high daily average intensity, those starting when soil moisture was high or those occurring when a combination of both conditions resulted in a relatively large proportion of runoff. The second group, referred to as low runoff producing storms, included storms having lower intensities and occurring when soil moisture was less which resulted in a smaller proportion of runoff.

The proper classification of each storm as to high or low runoff producing characteristics was found by totaling intensity and antecedent rainfall factors. These values were compared with the limits adopted for the high and low producing groups based on the plotted positions of the typical storms.

To determine the intensity factor for each storm the total depth of rainfall in the storm period was divided by the number of days of rain. This daily average was then multiplied by 10 for convenience in use. As a measure of soil moisture the antecedent rainfall which occurred during the 10 days preceding the first day of the storm under

consideration was used. The amount of rain on each day during the 10 day period was divided by the number of days by which that day of rain preceded the storm period. These results were totaled for the 10 days and their sum was multiplied by 60 to give this antecedent rainfall factor weight for use with the intensity factor. In the foregoing the days of rainfall and the amount of antecedent rainfall were determined on a weighted basis using the same Thiessen weighting factors that were developed for computing weighted rainfall on the tributary. To distinguish between antecedent rainfall and a storm period the determination was made on the following basis. In tributaries entering the Brazos below Paluxy Creek the storm period was considered to include all consecutive days on which the rainfall amounted to 0.5 inch or more. In Paluxy Creek and in tributaries entering the Brazos upstream from Paluxy Creek the storm period was considered to include all consecutive days on which the rainfall amounted to 0.75 inch or more.

The sum of the intensity and antecedent rainfall factors referred to was used to determine whether storms in tributaries not having stream gage records were of high or low runoff producing character. This procedure was unnecessary for those tributaries having stream gage records since it was possible to determine runoff directly from the stream hydrograph. Throughout the tributaries examined the value of the combined factors indicating the difference between the high and low runoff producing storms ranged from a value of 21 for Blackland Prairie tributaries to a maximum of 33 for the Forested Coastal Plains drainage areas.

The rainfall-runoff curves developed at each stream gage location could not be applied directly to smaller tributaries because of the differences in conservation problem areas or evaluation classes (land use and cover conditions) between the areas. The curves developed for the gage locations were adjusted to the smaller tributaries in the following manner. A weighted rainfall-runoff curve was prepared for the tributary using data developed from experimental and small watershed studies. In figure 13 are shown two sets of curves for evaluation classes in the Rolling Red Plains and Edwards Plateau conservation problem areas which were used in the development of a weighted rainfall-runoff curve for Mulberry Creek. Table 16 shows the computations used for developing the curve for present conditions. The depths of runoff in columns headed 1/ were read for various depths of rainfall on the proper curve in figure 13. The product of depth of runoff and the fractional part of the watershed contributing this runoff represented the weighted runoff from that evaluation class and was recorded in the proper column headed by 2/. The sum of all values in each column 2/ is proportional to the actual runoff to be expected from the given amount of rain. The same computations were completed for that part of the Clear Fork of the Brazos River above the Nugent stream gage. A ratio made by using the weighted values of runoff for Mulberry Creek and the Clear Fork was multiplied by the depth of runoff from the same rainfall on the drainage area above the Nugent stream gage. The rainfall-runoff relationship at Nugent had been determined by the method outlined at

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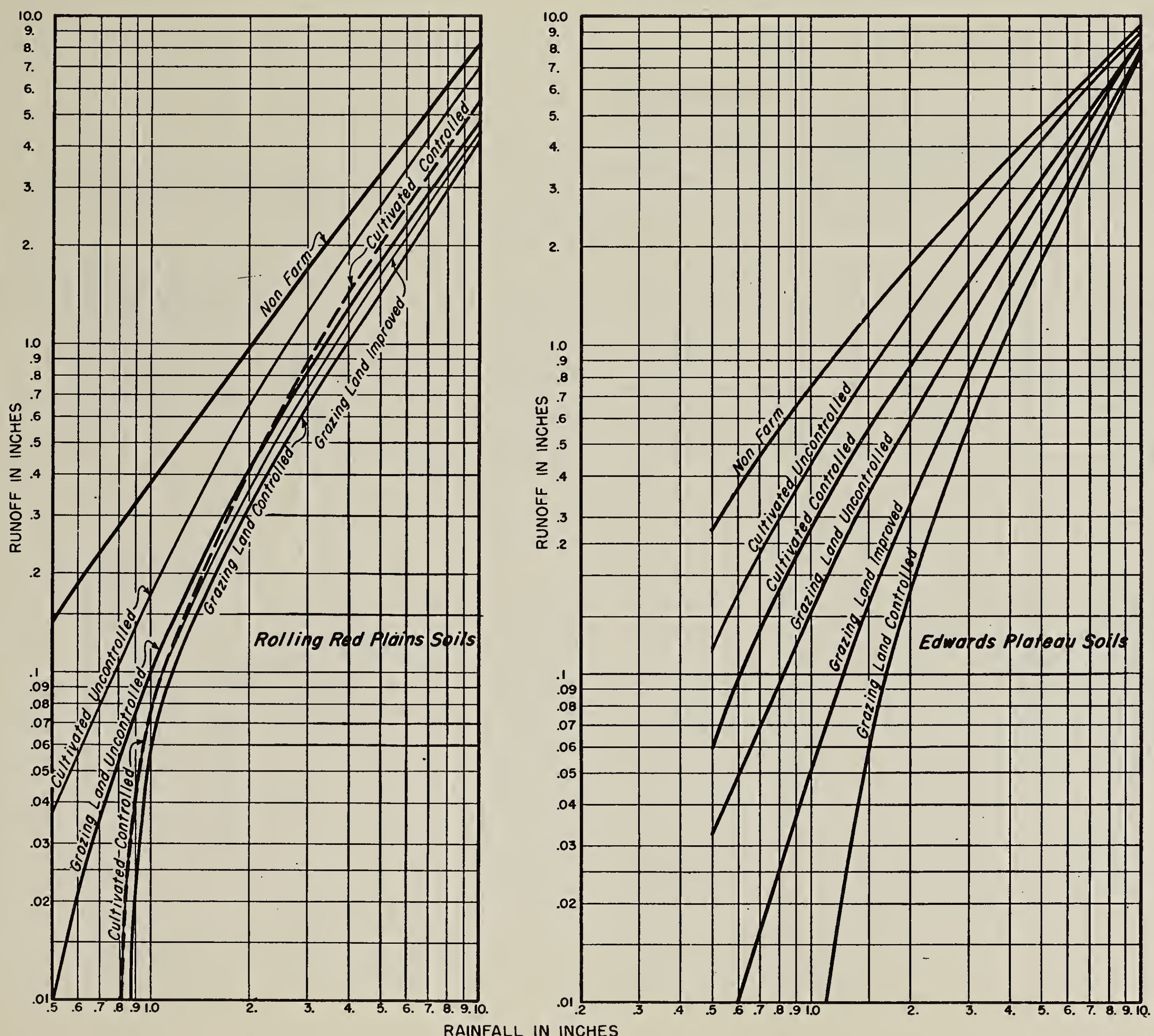


Figure 13

RAINFALL AND RUNOFF
RELATIONSHIP FOR SMALL AREAS
BRAZOS RIVER WATERSHED-TEXAS

E. A. T. 5-31-49 4-L-7245-21

Table 16. Derivation of Rainfall and Runoff Relationship Curve, Mulberry Creek, Valley Section No. 1, Present Conditions

Brazos River Watershed

| Soil and Condition | Drainage Area | Fractional part of Drainage Area | 1-inch Precipitation 1/ | 1-inch Precipitation 2/ | 4-inch Precipitation 1/ | 4-inch Precipitation 2/ | 8-inch Precipitation 1/ | 8-inch Precipitation 2/ | 10-inch Precipitation 1/ | 10-inch Precipitation 2/ |
|---|---|---|---|---|---|---|---|---|---|---|
| | (acres) | | | | | | | | | |
| **Rolling Red Plains** | | | | | | | | | | |
| Non-Farm | 4,093 | .0311 | .38 | .012 | 2.50 | .078 | 6.20 | .193 | 8.20 | .255 |
| Cultivated, controlled | 5,772 | .0438 | .08 | .004 | 1.45 | .064 | 4.05 | .177 | 5.60 | .245 |
| " uncontrolled | 47,019 | .3570 | .17 | .061 | 1.92 | .685 | 5.18 | 1.849 | 7.00 | 2.499 |
| Grazing land, controlled | 4,408 | .0335 | .06 | .002 | 1.03 | .035 | 3.00 | .100 | 4.20 | .141 |
| " " improved | 5,248 | .0399 | .08 | .003 | 1.17 | .047 | 3.25 | .130 | 4.50 | .179 |
| " " uncontrolled | 38,412 | .2916 | .10 | .029 | 1.30 | .379 | 3.50 | 1.021 | 4.80 | 1.400 |
| Sub-total | 104,952 | | | | | | | | | |
| **Edwards Plateau** | | | | | | | | | | |
| Non-Farm | 1,552 | .0118 | .74 | .009 | 3.75 | .044 | 7.44 | .088 | 9.30 | .110 |
| Cultivated, controlled | 80 | .0006 | .27 | 0 | 2.35 | .001 | 6.30 | .004 | 8.50 | .005 |
| " uncontrolled | 1,659 | .0126 | .43 | .005 | 3.18 | .040 | 7.20 | .091 | 9.00 | .113 |
| Grazing land, controlled | 2,568 | .0195 | 0 | 0 | 1.12 | .022 | 4.75 | .093 | 7.60 | .148 |
| Grazing land, improved | 1,177 | .0089 | .05 | 0 | 1.45 | .013 | 5.20 | .046 | 7.80 | .069 |
| Grazing land, uncontrolled | 19,716 | .1497 | .15 | .022 | 1.90 | .284 | 5.83 | .873 | 8.40 | 1.257 |
| Sub-total | 26,752 | | | | | | | | | |
| TOTALS | 131,704 | 1.0000 | | .147 | | 1.692 | | 4.665 | | 6.421 |

1/ Depth of runoff in inches.
2/ Weighted runoff from the evaluation class in inches.

the beginning of this section. Table 17 shows the method of relating computed runoff to observed runoff for four depths of rainfall.

Table 17 - Correction of Computed Runoff in Mulberry Creek

Brazos River Watershed

| Rainfall | Ratio 1/ | Runoff at Nugent | Corrected Runoff for Mulberry Creek |
|---|---|---|---|
| (inches) | | (inches) | (inches) |
| 1 | $\frac{.147}{.140}$ | .125 | .131 |
| 4 | $\frac{1.70}{1.63}$ | .790 | .823 |
| 8 | $\frac{4.67}{4.40}$ | 2.68 | 2.84 |
| 10 | $\frac{6.42}{5.99}$ | 3.98 | 4.26 |

1/ Weighted runoff computed for Mulberry Creek for present conditions from experimental data divided by the value for the same conditions in the Clear Fork above Nugent.

The values in the last column representing runoff in Mulberry Creek, adjusted to observed runoff in the gaged watershed most nearly comparable to Mulberry Creek, were used as plotting points for the Mulberry Creek rainfall-runoff curves shown in figure 14. The preceding computations were made for the conditions of high runoff producing storms. The curve for low runoff producing storms was derived by using the ratio between the high and low runoff producing storms on the area above the Nugent gage.

Figure 15 shows the relationship used between depth of runoff and peak discharge in Mulberry Creek. This curve was developed by determining, by the slope-area method, the discharge causing certain highwater marks found in the field survey. This discharge was plotted opposite the computed runoff causing the flow. The slope of the curve was determined by comparison with curves from similar gaged streams plotted on logarithmic cross-section paper.

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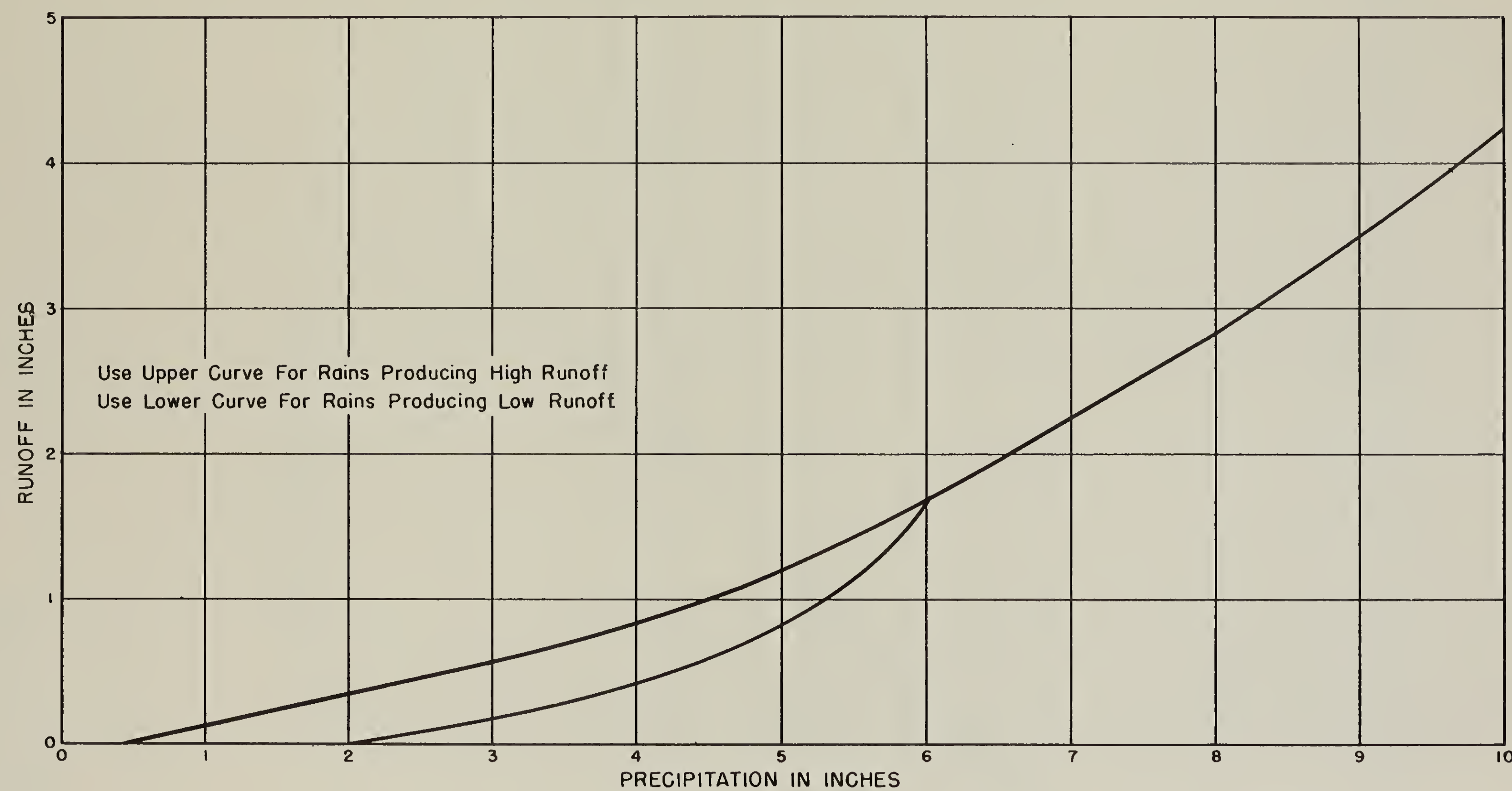


Figure 14

RAINFALL AND RUNOFF RELATIONSHIP
MULBERRY CREEK
BRAZOS RIVER WATERSHED - TEXAS

F. I. B. 6-2-49 4-L-7245-20

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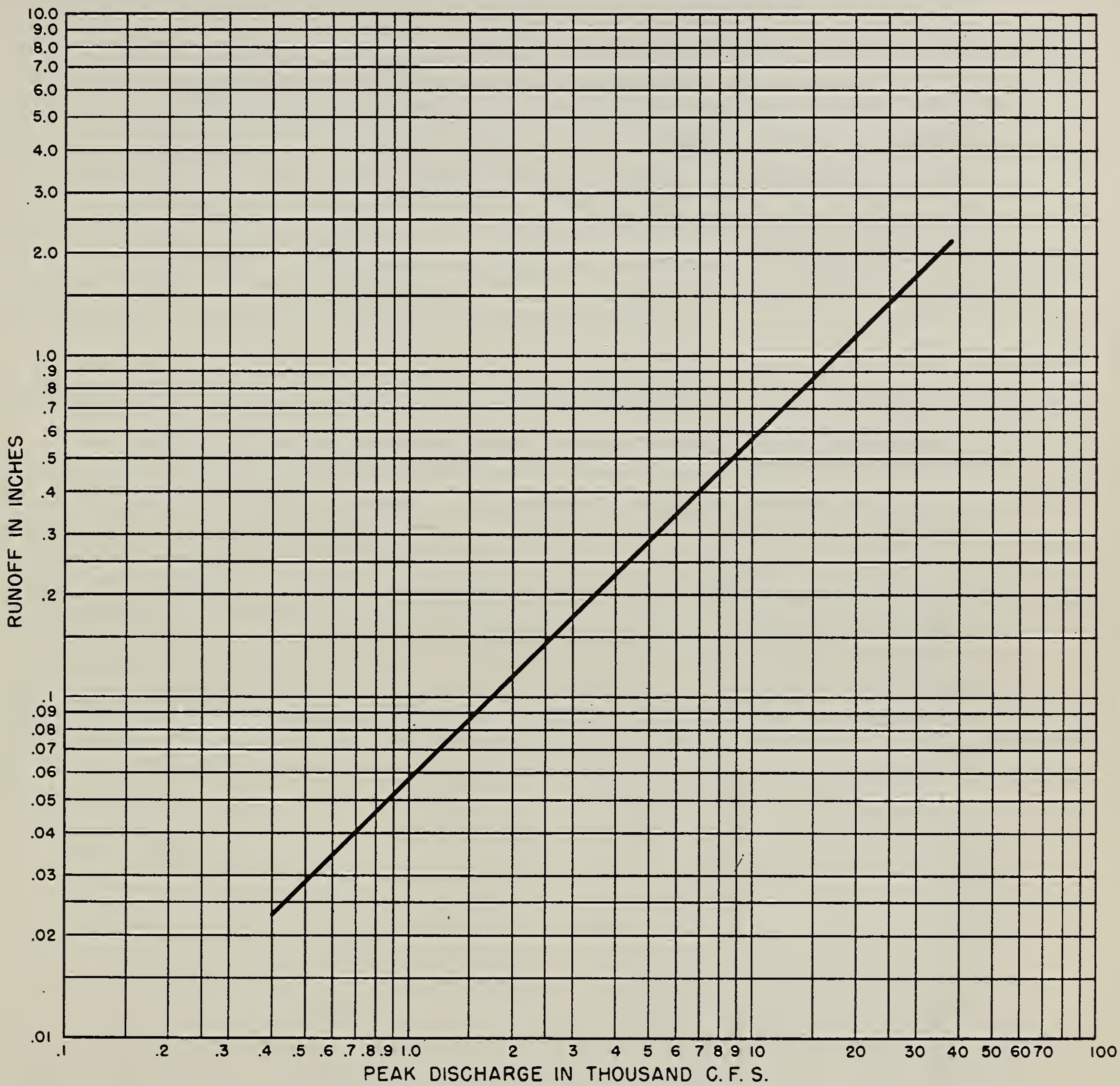


Figure 15

DEPTH OF RUNOFF AND PEAK
DISCHARGE RELATIONSHIP FOR MULBERRY CREEK
BRAZOS RIVER WATERSHED - TEXAS

F. I. B. 6-1-49 4-L-7245-18

## Reduction in Runoff

A curve for determining the effect of installation of the land treatment measures on the runoff to be expected from given amounts of rain was developed in the following manner. Using the area of land in each evaluation class, revised from present conditions to reflect the amounts of measures to be installed, table 18 was set up for the computation of runoff to be expected. The curve was plotted using runoff before treatment, Y, opposite runoff from the same amount of rainfall after installation of the land treatment measure, Y1, as shown in figure 16. Similar curves were developed for each sample tributary and subwatershed in which benefits from land treatment measures were computed. In the same figure is shown the curve giving the apparent runoff, Y2, after installation of floodwater retarding structures. The development of this second curve is explained under the heading, Floodwater Retarding Structures.

## Calculation of Flood Occurrences and Magnitudes

In Sample tributaries and small tributaries where adequate stream gage records were not available the flood series was determined in the following manner. All storms were selected which were capable of producing appreciable runoff in the tributary under consideration during the fifteen year period from January 1, 1933 through December 31, 1947. Several storms were eliminated from further consideration because they occurred shortly before or after another flood-producing storm. During the periods when a damaged crop could be replanted, the smaller flood was eliminated from consideration if two occurred within 15 days of each other. These periods are February through June and the month of October. During the non-replanting periods of July through September and November through January only the largest flood in each period was considered as being damage producing. Rainfall on a watershed was determined from the records of precipitation stations located in or sufficiently close to the watershed to be used in the Thiessen weighting method. In some tributaries it was necessary to use point rainfall from the nearest precipitation station having a long period of record. Figure 17 shows Mulberry Creek as an example. Weighted rainfall for the period from August 1940 through 1947 was computed from the records of precipitation at Abilene, Truby and Trent. Prior to this period, point rainfall measured at Abilene was used since this was the only station in operation close enough to the watershed for use.

## Calculation of Stream Discharge, Area Inundated and Damage.

Stream discharges and the corresponding depth of over-bank flow were computed at each valley cross-section for each 2-foot stage from bankful to the maximum flood elevation. Table 19 shows the typical computations used in the solution of Manning's formula for stream flow and the coefficient of roughness values used in determining the discharges. The relationship between discharge and stage were plotted as shown in figure 18.

Table 18. Derivation of Rainfall and Runoff Relationship Curve, Mulberry Creek, Valley Section No. 1, After Application of Land Treatment Measures.

Brazos River Watershed

| Soil and Condition | Drainage Area | Fractional part of Drainage Area | 1-inch Precipitation 1/ | 1-inch Precipitation 2/ | 4-inch Precipitation 1/ | 4-inch Precipitation 2/ | 8-inch Precipitation 1/ | 8-inch Precipitation 2/ | 10-inch Precipitation 1/ | 10-inch Precipitation 2/ |
|---|---|---|---|---|---|---|---|---|---|---|
| | (acres) | | | | | | | | | |
| Rolling Red Plains | | | | | | | | | | |
| Non-Farm | 4,093 | .0311 | .38 | .012 | 2.50 | .078 | 6.20 | .193 | 8.20 | .255 |
| Cultivated, controlled | 43,345 | .3291 | .08 | .026 | 1.45 | .477 | 4.05 | 1.333 | 5.60 | 1.843 |
| Cultivated, uncontrolled | 5,248 | .0399 | .17 | .007 | 1.92 | .077 | 5.18 | .207 | 7.00 | .279 |
| Grazing land, controlled | 21,305 | .1617 | .06 | .010 | 1.03 | .167 | 3.00 | .485 | 4.20 | .679 |
| Grazing land, improved | 26,133 | .1984 | .08 | .016 | 1.17 | .232 | 3.25 | .645 | 4.50 | .893 |
| Grazing land, uncontrolled | 4,828 | .0367 | .10 | .004 | 1.30 | .048 | 3.50 | .128 | 4.80 | .176 |
| Sub-total | 104,952 | | | | | | | | | |
| Edwards Plateau | | | | | | | | | | |
| Non-Farm | 1,552 | .0118 | .74 | .009 | 3.75 | .044 | 7.44 | .088 | 9.30 | .110 |
| Cultivated, controlled | 1,338 | .0102 | .27 | .003 | 2.35 | .024 | 6.30 | .064 | 8.50 | .087 |
| Cultivated, uncontrolled | 187 | .0014 | .43 | .001 | 3.18 | .004 | 7.20 | .010 | 9.00 | .013 |
| Grazing land, controlled | 7,972 | .0605 | 0 | 0 | 1.12 | .068 | 4.75 | .287 | 7.60 | .460 |
| Grazing land, improved | 13,349 | .1013 | .05 | .005 | 1.45 | .147 | 5.20 | .527 | 7.80 | .790 |
| Grazing land, uncontrolled | 2,354 | .0179 | .15 | .003 | 1.90 | .034 | 5.83 | .104 | 8.40 | .150 |
| Sub-total | 26,752 | | | | | | | | | |
| TOTALS | 131,704 | 1.0000 | | .096 | | 1.400 | | 4.071 | | 5.735 |

1/ Depth of runoff in inches.

2/ Weighted runoff from the evaluation class in inches.

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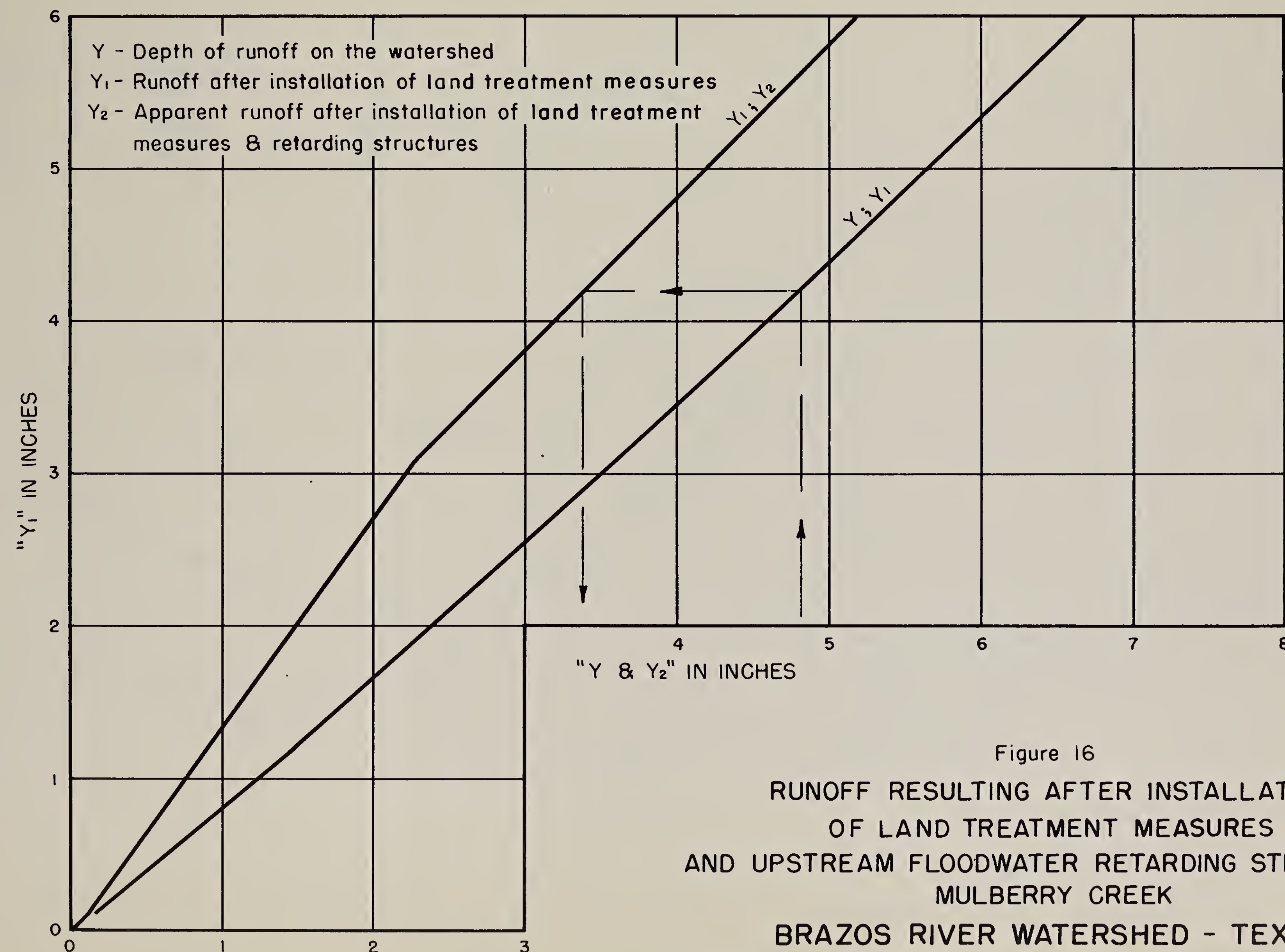


Figure 16

RUNOFF RESULTING AFTER INSTALLATION OF LAND TREATMENT MEASURES AND UPSTREAM FLOODWATER RETARDING STRUCTURES
MULBERRY CREEK
BRAZOS RIVER WATERSHED - TEXAS

REVISED 11-30-50 F.I.B. 5-27-49 4-L-7245-16

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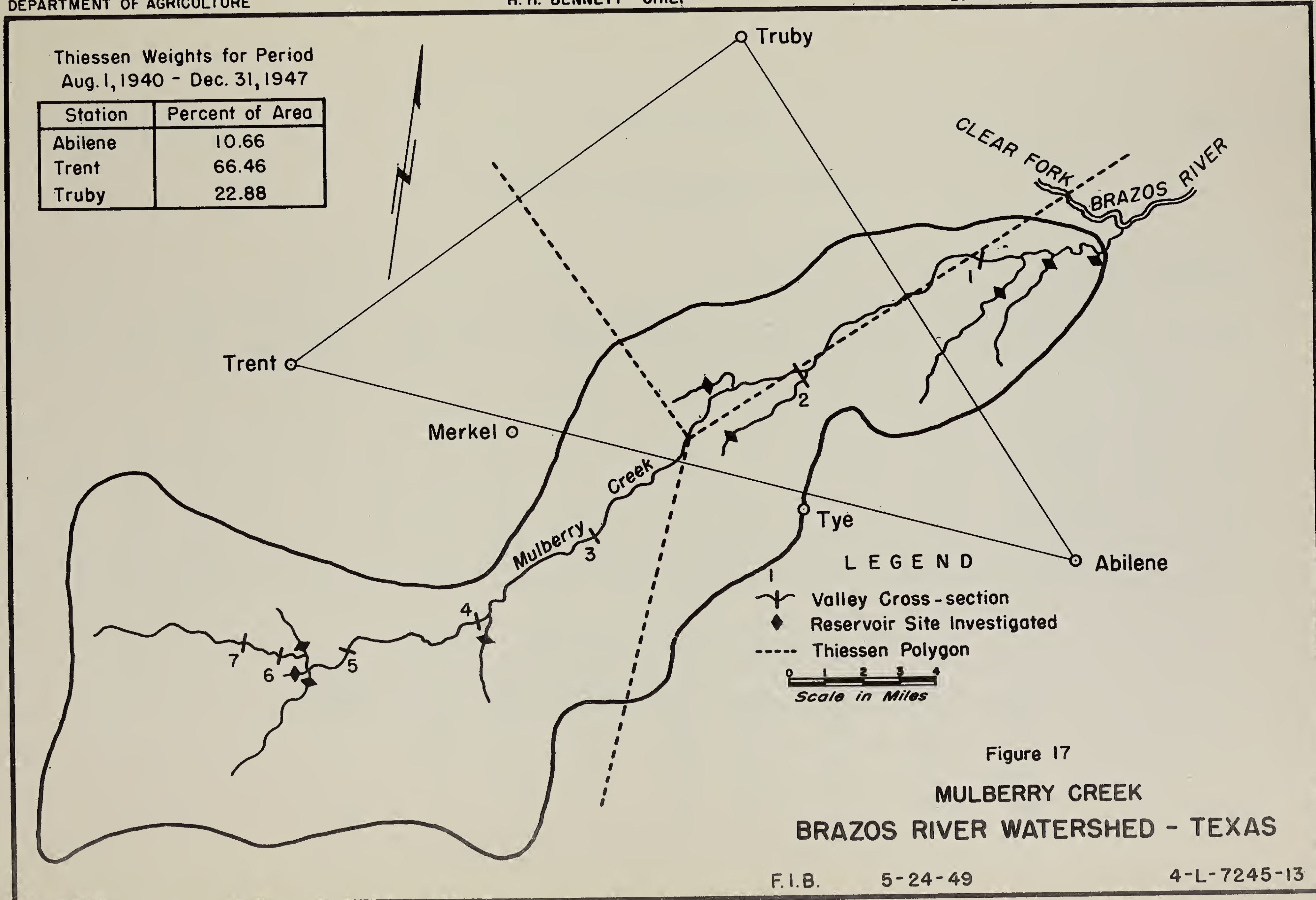


Thiessen Weights for Period
Aug. 1, 1940 - Dec. 31, 1947

| Station | Percent of Area |
|---|---|
| Abilene | 10.66 |
| Trent | 66.46 |
| Truby | 22.88 |

Figure 17

MULBERRY CREEK
BRAZOS RIVER WATERSHED - TEXAS

F.I.B. 5-24-49 4-L-7245-13

Table 19. Stream Discharge Computations for Section 3
Mulberry Creek

Brazos River Watershed

| Depth of Water Above Bankfull Stage feet | CHANNEL SECTION: Area of Section sq. ft. | Width of Water Surface feet | Wetted peri-meter feet | Hydraulic radius A/P | | Coeffi-cient of Roughness | 1.486 ar 2/3 / n | OVERFLOW SECTION: Area of Section sq. ft. | Width of Water Surface feet | Wetted peri-meter feet | Hydraulic radius A/P | | Coeff-icient of Rough-ness | 1.486 ar 2/3 / n | CHANNEL SECTION - OVERFLOW SECTION: Overflow Channel Sect. Combined | Slope of Water Surface | | Discharge c. f. s. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a | L | P | r | $r^{2/3}$ | n | Kd | a | L | P | r | $r^{2/3}$ | n | Kd | Kd | S | $S^{1/2}$ | Q |
| Bankfull | 210 | 45.0 | 46.9 | 4.48 | 2.718 | .060 | 14,140 | 350 | 230 | 230 | 1.52 | 1.322 | .055 | 12,500 | 26,640 | .0015 | .03873 | 1,030 |
| 2' Flooding | 320 | 45.0 | 46.9 | 6.82 | 3.596 | .065 | 26,310 | 885 | 330 | 330 | 2.68 | 1.929 | .045 | 56,370 | 82,680 | .0015 | .03873 | 3,200 |
| 4' Flooding | 430 | 45.0 | 46.9 | 9.17 | 4.381 | .065 | 43,070 | 1920 | 765 | 765 | 2.51 | 1.847 | .045 | 117,100 | 160,170 | .0015 | .03873 | 6,200 |
| 6' Flooding | 540 | 45.0 | 46.9 | 11.51 | 5.098 | .065 | 62,940 | 4075 | 1330 | 1330 | 3.06 | 2.108 | .045 | 283,670 | 346,610 | .0015 | .03873 | 13,420 |
| 8' Flooding | 650 | 45.0 | 46.9 | 13.86 | 5.770 | .065 | 85,740 | 7130 | 1610 | 1610 | 4.43 | 2.698 | .045 | 635,220 | 720,960 | .0015 | .03873 | 27,920 |
| 10' Flooding | 760 | 45.0 | 46.9 | 16.20 | 6.402 | .065 | 111,240 | 10490 | 1750 | 1750 | 5.99 | 3.298 | .045 | 1,142,420 | 1,253,660 | .0015 | .03873 | 48,550 |

Coefficients of Roughness 'n' in Mannings Formula

| Depth of Inundation in feet | Cotton | Small grain | Grain Sorghum | Corn | Pasture | Dense Weeds | Medium Woods | Dense Woods |
|---|---|---|---|---|---|---|---|---|
| 0-2 | .065 | .075 | .085 | .060 | .045 | .100 | .080 | .150 |
| 2-4 | .060 | .050 | .075 | .050 | .040 | .075 | .080 | .150 |
| 4-6 | .040 | .035 | .040 | .045 | .035 | .060 | .075 | .150 |
| 6-Over | .035 | .035 | .040 | .040 | .035 | .045 | .070 | .150 |

U. S. D. A. Technical Bulletin No. 129 "Flow of Water in Drainage Channels" was used as a guide for the selection of coefficients for the stream channel.

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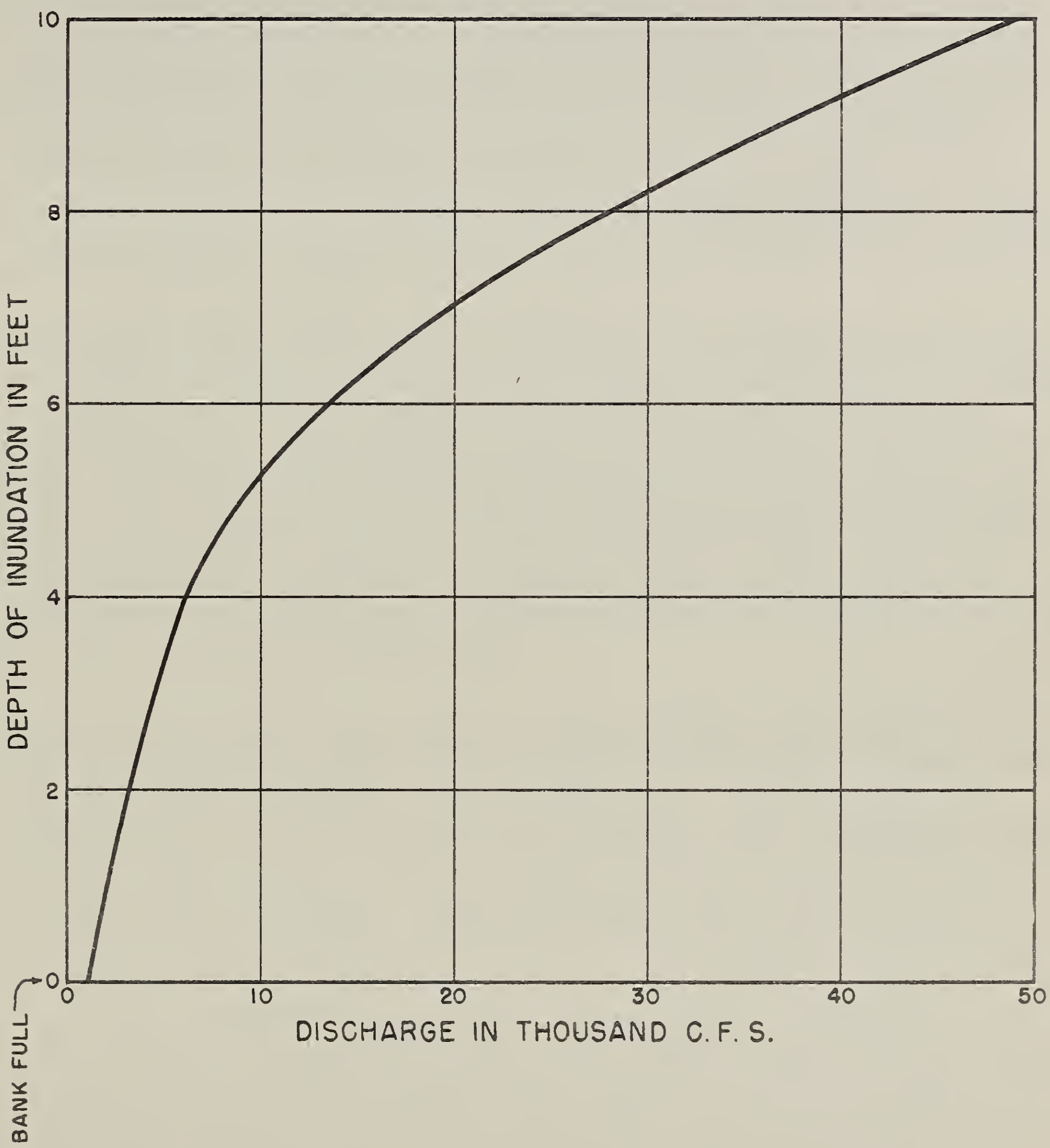


Figure 18

RATING CURVE FOR VALLEY CROSS-SECTION NO. 3 AT VALLEY MILE 17.7 ON MULBERRY CREEK

BRAZOS RIVER WATERSHED - TEXAS

F. I. B. 6-2-49 4-L-7245-19

The relationship existing between a given discharge at the valley cross-section used for the hydraulic control and the corresponding discharge at other parts along the stream was established by use of the theory of concordant flows. In this theory it is considered that the peak stream flow varies at different points with the relationship of drainage areas raised to some exponential power. Exponents used on the various streams varied from 0.26 to 0.90 as determined by comparison of stream gage records or of discharge rates computed from high-water marks found in the field survey. The range in values used for the exponent illustrate the extreme effect of drainage pattern and valley storage on stream flows found in the Brazos River Watershed. By use of this theory, flow factors were computed for each cross-section. The use of these factors permit the translation of any flow at the control section to equivalent flow at the various cross-sections as shown for Mulberry Creek in table 20.

The method described in the foregoing for computing stream discharge at various points was used in all tributaries and subwatersheds examined except in the lower part of the Clear Fork of the Brazos. In this reach the stream gage records available at Nugent, Fort Griffin and Crystal Falls were used directly to determine the magnitude of each flood used in the damage-producing series at each gage location. The rates of discharge at points between the gages were considered to vary in proportion to the size of drainage area. A straight line relationship was used which was obtained by plotting discharge against drainage area on log-log coordinates.

The area of inundation, exclusive of channel, was computed by 2-foot depth increments, from zero to six feet, for each reach represented by each cross-section. These areas were computed for each 2-foot stage at the flood plain control section. The concordant flow factor and the section rating curves already described were used to determine the stage at each cross-section properly associated with the stage at the control section. Table 20 shows the acres inundated in Mulberry Creek sample tributary for the 7.7-foot stage. These areas were obtained by measuring on each cross-section, similar to figure 19, the width of valley inundated in each depth increment. These widths were converted to acres by multiplying with the length factor determined for each cross-section and the results, when totaled, were tabulated for use with the damage factors as is explained later. In addition, it was necessary to determine areas flooded in unsurveyed small tributaries to the main stream. This was done by prorating areas inundated, by depth increments, from the surveyed cross-sections to the unsurveyed reaches on the basis of similarity. This proration was made either on a linear or size of drainage area basis as found most suitable from field observation.

The value of damage caused in the tributaries and main streams was calculated according to the season in which the flood occurred, as shown in table 21. The total value of damage and the total area inundated were

Table 20. Area Inundated by Flood Causing Overflow of 7.7 Feet Above Bankful Stage at Section 3, Mulberry Creek

Brazos River Watershed

| Sect. No. | Drainage Area | Concordant Flow Factor 1/ | Discharge | Total Width | Distance Applied | Total Flooded | Factor 2/ | Width and Area Flooded at Various Depths: 0'-2' | | 2'-4' | | 4'-6' | | 6' and above | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (sq.mi.) | | (C.F.S.) | (ft.) | (miles) | (acres) | | (feet) | (acres) | (feet) | (acres) | (feet) | (acres) | (feet) | (acres) |
| 1 | 209.0 | 1.000 | 36,300 | 3,823 | 5.75 | 1,936 | .50658 | 648 | 328 | 1,943 | 984 | 1,122 | 568 | 110 | 56 |
| 2 | 186.8 | .904 | 32,800 | 2,475 | 6.81 | 2,569 | 1.03783 | 80 | 83 | 1,285 | 1,334 | 860 | 893 | 250 | 259 |
| 3 | 128.1 | .700 | 25,400 | 1,565 | 7.12 | 1,750 | 1.11850 | 320 | 358 | 540 | 604 | 400 | 447 | 305 | 341 |
| 4 | 101.3 | .587 | 21,300 | 1,245 | 4.06 | 717 | .57631 | 65 | 37 | 271 | 156 | 636 | 367 | 273 | 157 |
| 5 | 62.4 | .419 | 15,200 | 1,152 | 3.05 | 196 | .16997 | 93 | 16 | 531 | 90 | 528 | 90 | - | - |
| 6 | 45.4 | .331 | 12,000 | 727 | 1.88 | 196 | .26859 | 250 | 67 | 178 | 48 | 66 | 18 | 233 | 63 |
| 7 | 19.5 | .187 | 6,800 | 1,122 | 1.68 | 137 | .12219 | 1,122 | 137 | - | - | - | - | - | - |
| 3/ | - | - | - | - | - | 819 | - | - | 819 | - | - | - | - | - | - |
| Totals - | | - | - | - | - | 8,320 | - | - | 1,845 | - | 3,216 | - | 2,383 | - | 876 |

1/ Based on ratio of drainage areas and concordant flow exponent of 0.7.
2/ Acres flooded per one-foot of valley width.
3/ Prorated areas on minor headwater streams similar to surveyed stream.

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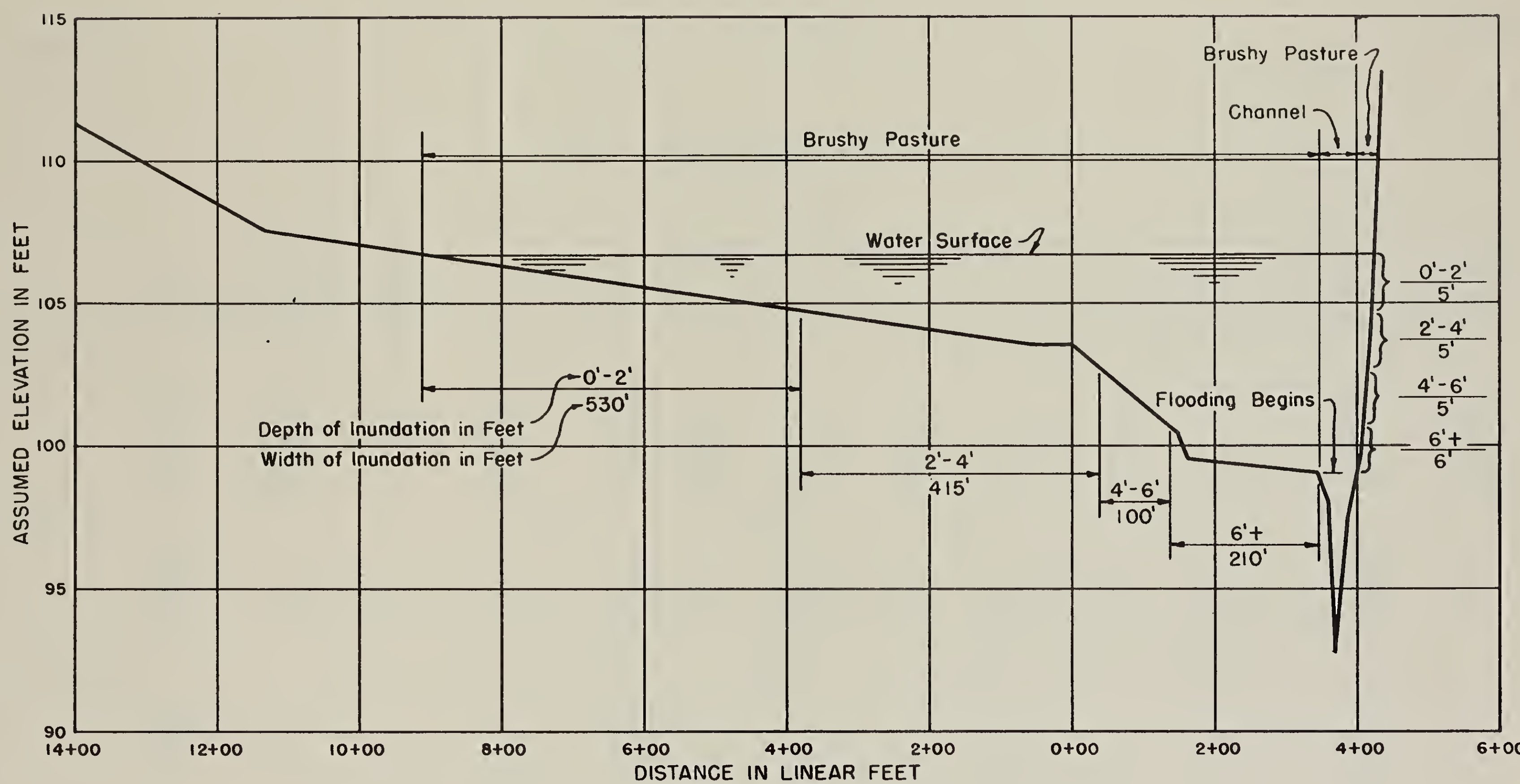


Figure 19

VALLEY CROSS-SECTION NO. 3
AT VALLEY MILE 17.7 ON MULBERRY CREEK
SHOWING FLOOD PLAIN INUNDATION
BRAZOS RIVER WATERSHED - TEXAS

F.I.B. 6-1-49 4-L-7245-17

Table 21. Runoff - Damage Relationship
Mulberry Creek

Brazos River Watershed

| Season | Runoff Y or Yl 1/ | Discharge and Stage at Control Section 2/ | 3/ | Area Flooded and Damage at Various Depths 0'-2' | | 2'-4' | | 4'-6' | | 6' and Above | | Total Damage | Total Area Inundated |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (inches) | (c.f.s.) | (feet) | (acres) | (dollars) | (acres) | (dollars) | (acres) | (dollars) | (acres) | (dollars) | (dollars) | (acres) |
| July-October Damage Factor 4/ | - | - | - | $0.76 | | $1.08 | | $1.19 | | $1.22 | | | |
| | 0.082 | 1,030 | 0.0 | 546 | 415 | 0 | 0 | 0 | 0 | 0 | 0 | 415 | 546 |
| | 0.26 | 3,200 | 2.0 | 2,101 | 1,597 | 550 | 594 | 0 | 0 | 0 | 0 | 2,191 | 2,651 |
| | 0.50 | 6,200 | 4.0 | 2,915 | 2,215 | 1,500 | 1,620 | 269 | 320 | 0 | 0 | 4,155 | 4,684 |
| | 1.08 | 13,420 | 6.0 | 3,576 | 2,718 | 2,811 | 3,036 | 829 | 987 | 252 | 307 | 7,048 | 7,468 |
| | 2.08 | 25,400 | 7.7 | 1,845 | 1,402 | 3,216 | 3,473 | 2,383 | 2,836 | 876 | 1,069 | 8,780 | 8,320 |
| April-June Damage Factor 4/ | | | | 1.11 | | 1.50 | | 1.77 | | 1.91 | | | |
| | 0.082 | | | | 606 | | 0 | | 0 | | 0 | 606 | |
| | 0.26 | | | | 2,332 | | 825 | | 0 | | 0 | 3,157 | |
| | 0.50 | As above | As above | As above | 3,236 | As above | 2,250 | As above | 476 | As above | 0 | 5,962 | As above |
| | 1.08 | | | | 3,969 | | 4,216 | | 1,467 | | 481 | 10,133 | |
| | 2.08 | | | | 2,048 | | 4,824 | | 4,218 | | 1,673 | 12,763 | |
| November-March Damage Factor 4/ | | | | 0.44 | | 0.94 | | 1.22 | | 1.27 | | | |
| | 0.082 | | | | 240 | | 0 | | 0 | | 0 | 240 | |
| | 0.26 | | | | 924 | | 517 | | 0 | | 0 | 1,441 | |
| | 0.50 | | | | 1,283 | | 1,410 | | 328 | | 0 | 3,021 | |
| | 1.08 | As above | As above | As above | 1,573 | As above | 2,642 | As above | 1,011 | As above | 320 | 5,546 | As above |
| | 2.08 | | | | 812 | | 3,023 | | 2,907 | | 1,113 | 7,855 | |

1/ Depth of runoff from the watershed.
2/ Discharge at valley section 3 corresponding to items under 1/ and 3/.
3/ Height above bankfull.
4/ Damage on 1 acre inundated for season and depth of flooding.

Flooding begins for Y or Yl = 0.082 inches.

plotted opposite the inches of runoff causing the stage associated with the damage as illustrated in figure 20. Similar curves (figure 21) were computed to show total damage above and below floodwater retarding structures after they are constructed. No damage was computed for the area flooded by these structures.

The storm series used for studying the flood damage in Mulberry Creek is shown in table 22. A brief outline of the source of the data in the table is given in the following. The development of the criteria enabling designation of each storm as being a high or low runoff producer has been explained in the preceding section "Rainfall-Runoff Relationship." Using this designation the appropriate line was read on figure 14 opposite the amount of precipitation shown in order to obtain the value of Y, or depth of runoff in inches for present conditions of land use. The total area inundated and the value of damage were taken from the appropriate curves in figure 20. The depth of runoff, Y1, after the affect of installation of land treatment measures was read from the proper curve in figure 16 the area inundated and the value of damage were then obtained from figure 20. The apparent runoff (meaning of this term is explained in the following section) after installation of floodwater retarding structures was read from the proper curve on figure 21 and the new area flooded and the value of damage was obtained by totaling the values read from the two sets of curves on figure 21. The average annual damage was computed for the conditions prior to treatment, after installation of the land treatment measures, and after installation of the recommended program. These values were applied to the areas considered similar to the sample as explained in Appendix IV and were summarized by subwatersheds (figure 3). The subwatersheds were selected on the bases of drainage area characteristics, hydrologic controls (such as reservoirs or stream gages) and damages.

The foregoing procedure as outlined for Mulberry Creek was repeated for all subwatersheds and small tributaries in which flood damages were examined except that the damage producing series and runoff were determined from stream gage records, when available, instead of from rainfall.

In the lower Clear Fork between Nugent and Crystal Falls, as has been explained, the theory of concordant flow was not employed. Because each flood was routed separately through this reach the damage curves referred to were not used. Instead areas inundated by depth increments were computed at each cross-section and these areas were used with the corresponding damage factors to determine the total damage for each flood.

In the foregoing, references to the recommended program imply the use of various combinations of measures in different tributaries. The effect of installation of land treatment or conservation measures was evaluated in all tributaries. The proposed amounts of these measures varies between tributaries, and the effect of such variation is reflected in the rainfall-runoff relationship developed for the tributaries. The influence of floodwater retarding structures on flood damage was

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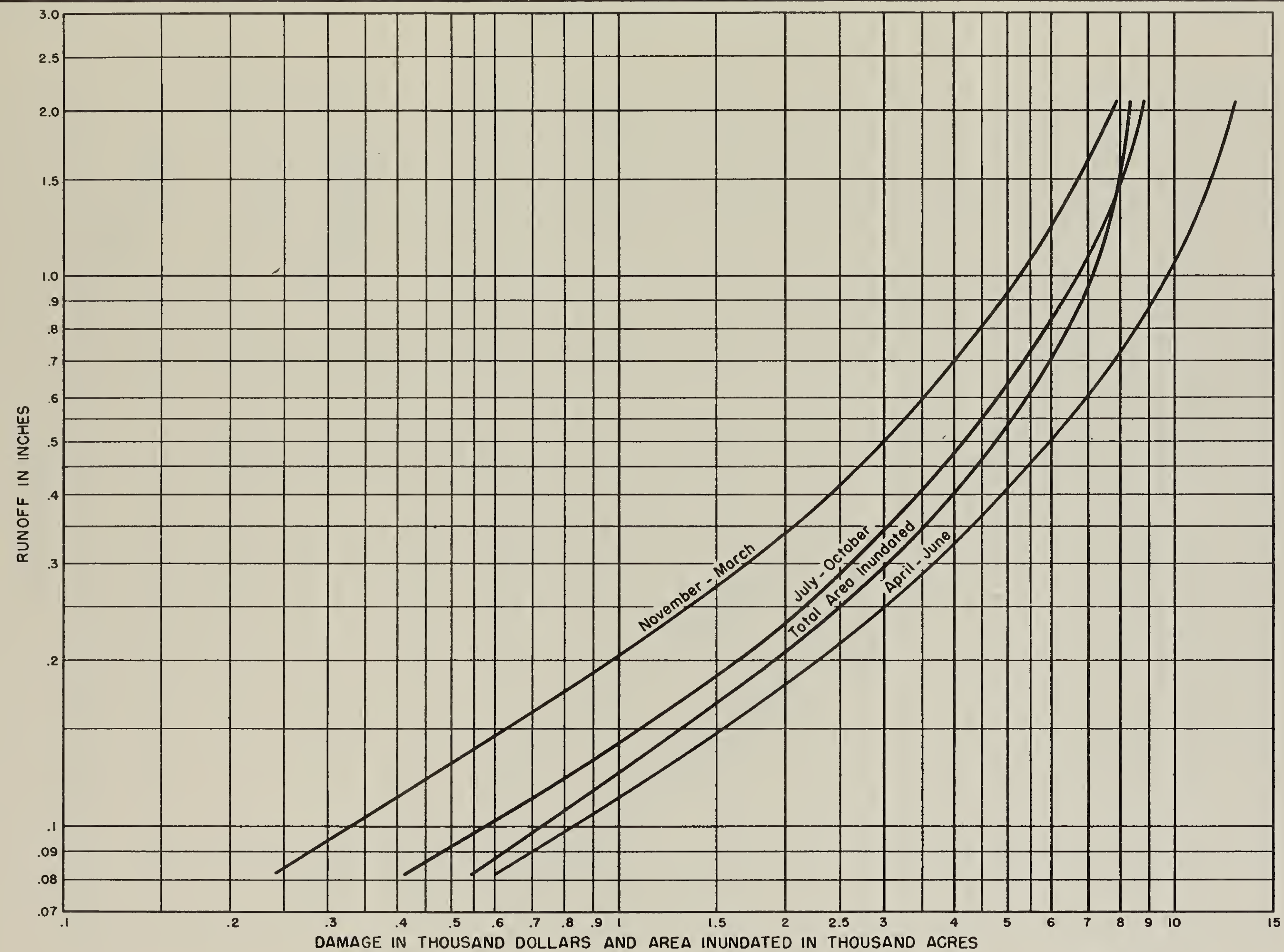


Figure 20
RUNOFF AND DAMAGE RELATIONSHIP FOR CONDITIONS
AFTER INSTALLATION OF THE LAND TREATMENT MEASURES
MULBERRY CREEK
BRAZOS RIVER WATERSHED - TEXAS

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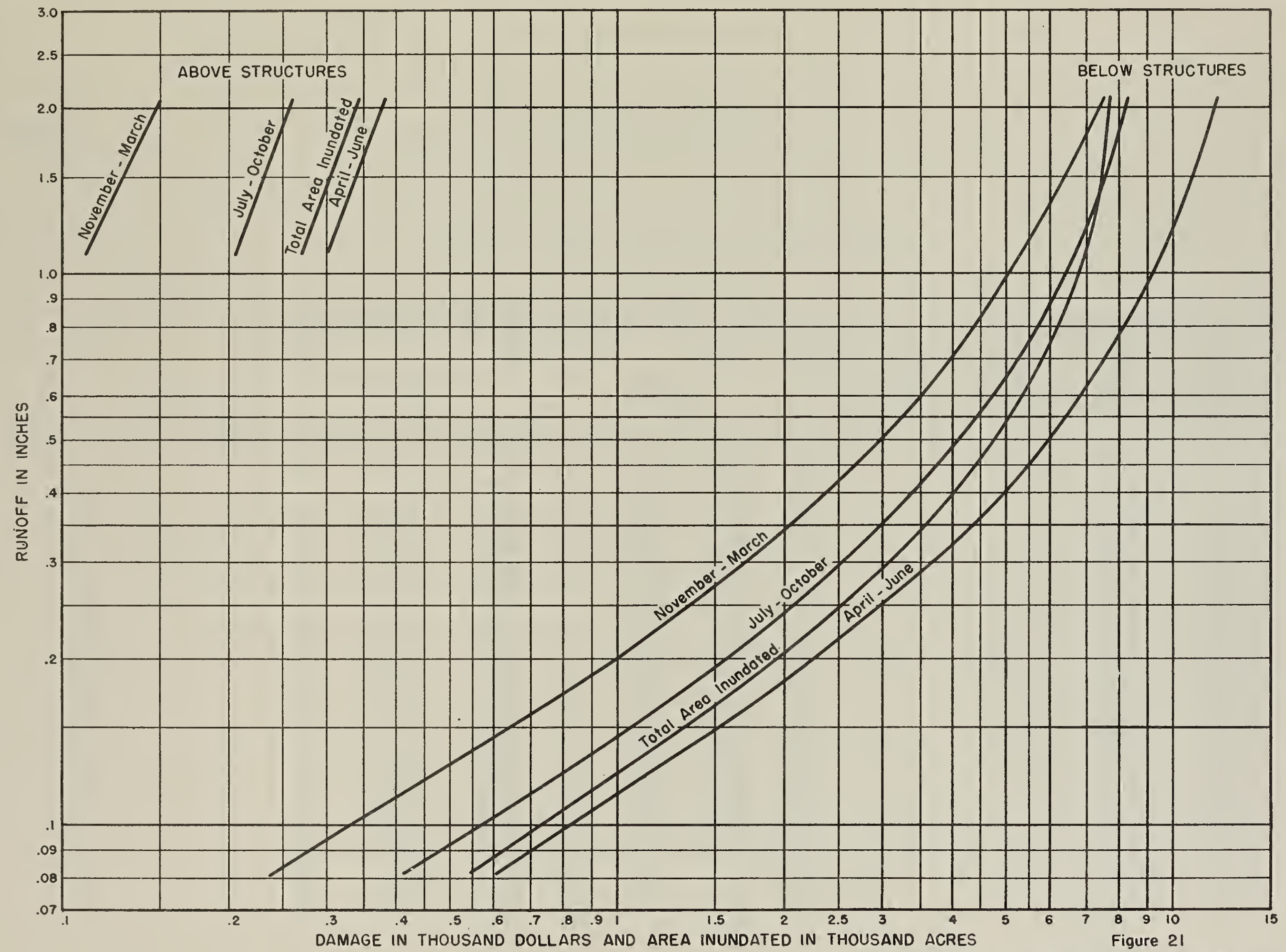


Figure 21

RUNOFF & DAMAGE RELATIONSHIP ABOVE & BELOW FLOODWATER RETARDING STRUCTURES AFTER INSTALLATION OF THE RECOMMENDED PROGRAM

MULBERRY CREEK

BRAZOS RIVER WATERSHED - TEXAS

F. I. B. 5-26-49 4-L-7245-14

Table 22 - Damage-Producing Storms - Mulberry Creek

Brazos River Watershed

| Date | Precipi-tation | Criteria 1/ Low | Criteria 1/ High | Present Condition of Land Use: Runoff Y | Present Condition of Land Use: Area Flooded | Present Condition of Land Use: Damage | With Land Treatment Measures: Runoff Y1 | With Land Treatment Measures: Area Flooded | With Land Treatment Measures: Damage | With Land Treatment Measures: Runoff Y2 2/ | With Recommended Program: Area Flooded Above Structures | With Recommended Program: Damage Above Structures | With Recommended Program: Area Flooded Below Structures | With Recommended Program: Damage Below Structures | Total Damage Above and Below Structures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (inches) | | | (inches) | (acres) | (dollars) | (inches) | (acres) | (dollars) | (inches) | (acres) | (dollars) | (acres) | (dollars) | (dollars) |
| May 23-24, 1933 | 3.79 | | x | .77 | 6,300 | 8,300 | .60 | 5,400 | 6,900 | .47 | - | - | 4,540 | 5,680 | 5,680 |
| February 8, 1935 | 1.05 | | x | .15 | 1,280 | 620 | .11 | 835 | 383 | .11 | - | - | 835 | 383 | 383 |
| May 14-17, 1935 | 4.36 | x | | .55 | 5,100 | 6,450 | .42 | 4,120 | 5,100 | .35 | - | - | 3,570 | 4,360 | 4,360 |
| June 12-15, 1935 | 3.26 | x | | .23 | 2,250 | 2,680 | .17 | 1,530 | 1,810 | .16 | - | - | 1,420 | 1,660 | 1,660 |
| September 2, 1935 | 2.35 | | x | .43 | 4,200 | 3,630 | .33 | 3,310 | 2,860 | .28 | - | - | 2,850 | 2,360 | 2,360 |
| September 15-17, 1936 | 5.14 | x | | .90 | 6,850 | 6,320 | .72 | 6,050 | 5,450 | .56 | - | - | 5,100 | 4,500 | 4,500 |
| August 21, 1937 | 2.20 | | x | .40 | 3,980 | 3,420 | .31 | 3,120 | 2,680 | .26 | - | - | 2,650 | 2,190 | 2,190 |
| March 26-28, 1938 | 3.81 | x | | .37 | 3,720 | 2,180 | .27 | 2,720 | 1,480 | .23 | - | - | 2,280 | 1,210 | 1,210 |
| May 21, 1938 | 4.25 | | x | .91 | 6,860 | 9,200 | .72 | 6,050 | 7,920 | .56 | - | - | 5,100 | 6,470 | 6,470 |
| June 8, 1938 | 1.70 | | x | .28 | 2,850 | 3,410 | .20 | 1,880 | 2,260 | .19 | - | - | 1,800 | 2,120 | 2,120 |
| July 20-24, 1938 | 6.72 | | x | 2.08 | 8,320 | 8,780 | 1.73 | 8,150 | 8,460 | 1.28 | 287 | 218 | 7,250 | 7,150 | 7,368 |
| May 27-28, 1939 | 2.36 | | x | .43 | 4,200 | 5,200 | .33 | 3,320 | 4,040 | .28 | - | - | 2,850 | 3,410 | 3,410 |
| June 18-20, 1939 | 3.62 | x | | .32 | 3,260 | 3,930 | .24 | 2,380 | 2,850 | .22 | - | - | 2,160 | 2,550 | 2,550 |
| October 9, 1939 | 1.52 | | x | .25 | 2,500 | 2,130 | .18 | 1,640 | 1,420 | .17 | - | - | 1,550 | 1,270 | 1,270 |
| May 2, 1941 | 2.28 | | x | .42 | 4,120 | 5,100 | .31 | 3,120 | 3,800 | .26 | - | - | 2,650 | 3,130 | 3,130 |
| May 21, 1941 | 2.42 | | x | .45 | 4,380 | 5,400 | .34 | 3,420 | 4,170 | .28 | - | - | 2,850 | 3,410 | 3,410 |
| June 10, 1941 | 1.49 | | x | .24 | 2,380 | 2,850 | .18 | 1,640 | 1,960 | .17 | - | - | 1,530 | 1,820 | 1,820 |
| October 15, 1941 | 3.48 | | x | .70 | 5,950 | 5,330 | .55 | 5,100 | 4,460 | .44 | - | - | 4,330 | 3,690 | 3,690 |
| September 7, 1942 | 2.23 | | x | .40 | 3,980 | 3,420 | .31 | 3,120 | 2,680 | .26 | - | - | 2,650 | 2,190 | 2,190 |
| October 16-17, 1942 | 3.77 | x | | .36 | 3,630 | 3,020 | .27 | 2,720 | 2,320 | .23 | - | - | 2,280 | 1,880 | 1,880 |
| May 22, 1944 | 1.13 | | x | .17 | 1,530 | 1,810 | .12 | 945 | 1,080 | .12 | - | - | 945 | 1,080 | 1,080 |
| July 21-22, 1944 | 2.91 | x | | .15 | 1,280 | 1,090 | .11 | 835 | 665 | .11 | - | - | 835 | 665 | 665 |
| August 8, 1945 | 2.55 | x | | .09 | 615 | 480 | .08 | - | - | .08 | - | - | - | - | - |
| October 9, 1945 | 1.08 | | x | .15 | 1,280 | 1,090 | .11 | 835 | 665 | .11 | - | - | 835 | 665 | 665 |
| May 10, 1947 | 1.95 | | x | .34 | 3,420 | 4,170 | .25 | 2,500 | 2,980 | .22 | - | - | 2,160 | 2,550 | 2,550 |
| June 20, 1947 | .91 | | x | .11 | 835 | 950 | .07 | - | - | .07 | - | - | - | - | - |

Flood Stage: Runoff = 0.082 inches.

1/ See explanation of method used for classifying storms as producing high or low runoff.

2/ Use Y1 for Area above Structures.

evaluated in those tributaries having sites available. The installation of structures was included as a part of the recommended program in only those areas where the benefit from the expected reduction in flooding would justify the expense of installation and maintenance. In the same manner the justification for channel improvement was examined in several tributaries and the recommendation for the extent of application of this measure was made dependent on the benefit-cost ratio found in these examinations.

The maximum areas of inundation as determined for the largest flood in the damage-producing series used in each of the sample tributaries are shown in table 23. Sample tributaries from the Little River and Bosque River Watershed Surveys are included in this table.

Table 23. Area Inundated in Sample Tributaries

Brazos River Watershed

| Conservation Problem Area | Sample Tributary | Area Inundated 1/ |
|---|---|---|
| | | (percent) |
| Reddish Prairie | Colony | 5.98 |
| Reddish Prairie | Palo Pinto | 2.23 |
| Reddish Prairie | Keechi | 1.87 |
| Cross Timbers | Duncan | 3.89 |
| Cross Timbers | North Bosque | 5.35 |
| Grand Prairie | Dodds | 7.65 |
| Grand Prairie | School | 3.15 |
| Grand Prairie | Neil | 4.23 |
| Grand Prairie | Harris | 6.11 |
| Blackland Prairie | Darrs | 5.22 |
| Blackland Prairie | O'possum | 4.97 |
| Blackland Prairie | S. Bosque | 3.85 |
| Blackland Prairie | New Years | 4.37 |
| Blackland Prairie | Navasota | 10.82 |
| Forested Coastal Plain | Nails | 9.11 |
| Rolling Red Plains | Mulberry | 5.63 |
| Rolling Red Plains | Lake | 7.03 |

1/ The area inundated by the **maximum** flood in the damage-producing flood series, expressed as percent of drainage area.

Channel Improvement

Investigations were made to determine the need for improving channel capacities in a number of streams in the Blackland Prairie area of the watershed. The curve shown in figure 22 was used as a basis for determining the minimum desirable capacity of channels. This curve represents the mean between the maximum and minimum curves for hill areas developed for the Texas Gulf Coastal area by the Water Conservation Division of Region 4, Soil Conservation Service. Flooding will not be eliminated by the provision of channel capacities found necessary by use of this curve; but the duration of inundation will be shortened sufficiently to avoid damage to crops because of poor drainage. The benefits to be expected from channel improvement were determined by comparing damages resulting from inundation by a flood series before installation of the improvement with the damage remaining after the improvement.

Channels were estimated on the basis of 2 on 1 side slopes and capacities were computed using Manning's formula with the 'n' value of .03 for grazed sod in good condition. Allowance was made for usable old channel and it was found that excavated material would balance the quantity of fill needed to level all the flood plain, except for the unused portion of the main channel. Computations were based on valley cross-sections surveyed for use in the examination of flood damage and benefits.

The need for channel improvement was investigated in the following subwatersheds:

| | |
|---|---|
| Castleman Creek | 3.2 miles |
| Navasota Sample watershed | 6.3 " |
| Navasota River | 21.0 " |
| Tehuacana Creek | 11.9 " |
| New Years Creek | 22.9 " |
| Turkey Creek | 6.4 " 1/ |

Castleman Creek was considered typical of small streams with inadequate channels entering the Brazos River directly. In addition there are 5 other small streams similar to Castleman in which a total of 4 miles of channel should be improved. The size of drainage area of Castleman Creek and the similar subwatersheds averages 22 square miles.

Channel improvement was estimated for unsurveyed streams by comparison with survey streams as follows:

| | |
|---|---|
| Pond Creek | 21 miles |
| East Fork of Mill Creek | 15 miles |
| Navasota River tributaries | 14 miles |

The average size drainage area of the above streams is about 120 square miles.

1/ Little River Watershed Survey.

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
H. H. BENNETT-CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL-REGIONAL CONSERVATOR

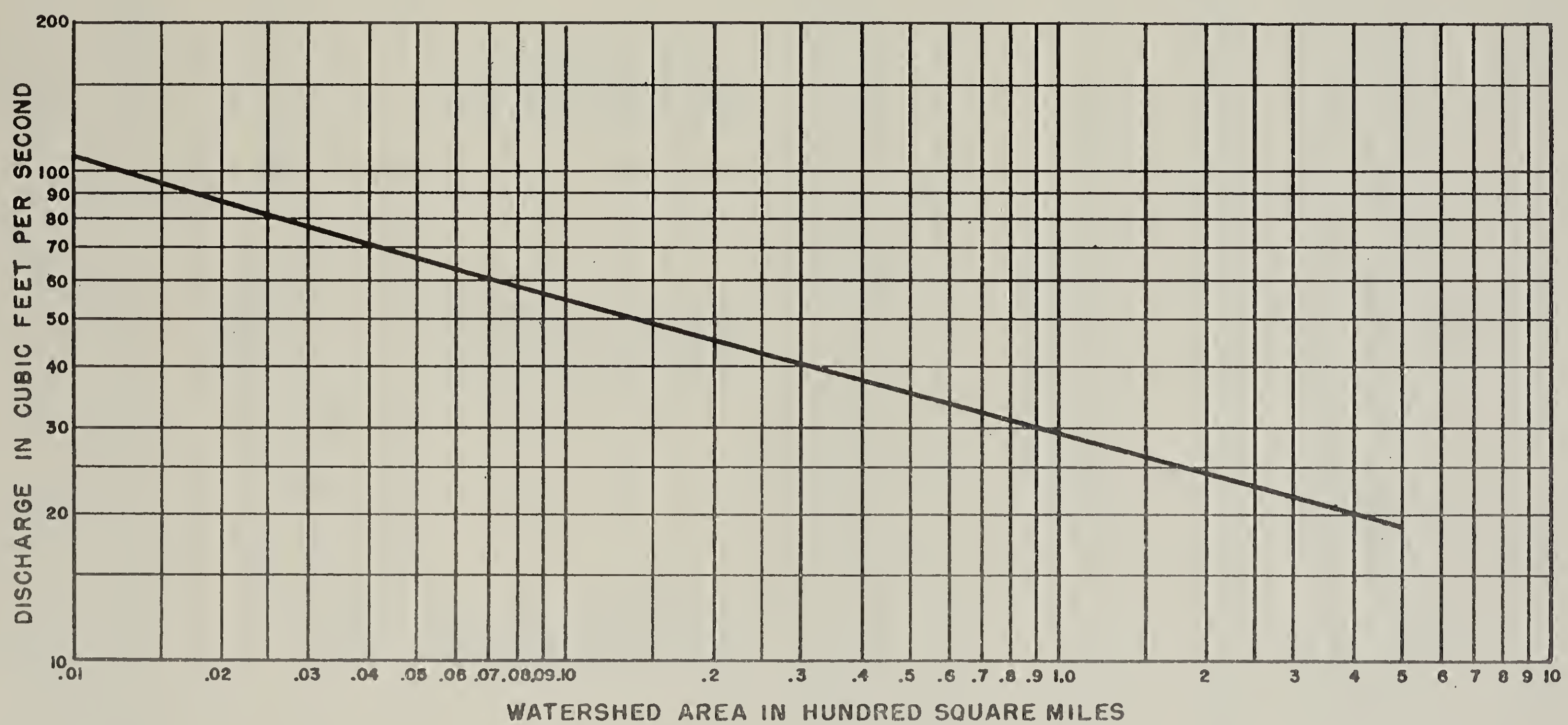


Figure 22
DRAINAGE RUNOFF CURVE
BRAZOS RIVER WATERSHED - TEXAS

4 - L - 7245-25

Floodwater Retarding Structures

Field reconnaissance, site surveys, and additional analysis revealed that sites for a system of retarding structures are available in a number of the subwatersheds. Areas in which floodwater retarding structures are recommended are shown in figure 29, page 187.

The examination of the effect on flood damage of the floodwater retarding structures in Mulberry Creek is given as an example of the method of analysis used. However, it appears at the present time that such structures cannot be included economically as a part of the recommended program in Mulberry Creek and similar areas.

The weighted amount of floodwater retarding storage, on the entire sample tributary, was computed as shown in table 24.

Table 24. Storage Capacity of Floodwater Retarding Structures
Mulberry Creek
Brazos River Watershed

| Location | Floodwater Retarding Storage | | Drainage Area | Product |
|---|---|---|---|---|
| (site no.) | (acre-feet) | (inches of runoff) | (sq. miles) | (inch-miles) |
| 2 | 898 | 3.62 | 4.65 | 16.83 |
| 3 | 813 | 2.20 | 6.93 | 15.25 |
| 4 | 2817 | 2.49 | 21.21 | 52.81 |
| 5 | 515 | 3.62 | 2.67 | 9.67 |
| 6 | 1120 | 3.62 | 5.80 | 21.00 |
| 7 | 1597 | 3.62 | 8.27 | 29.94 |
| 8 | 761 | 3.62 | 3.94 | 14.26 |
| 9 | 1508 | 3.62 | 7.81 | 28.27 |
| 10 | 898 | 3.62 | 4.65 | 16.83 |
| Totals | - | - | 65.93 | 204.86 |

Weighted depth of runoff $= \frac{204.86}{65.93} = 3.11$ inches.

The apparent reduction in runoff in Mulberry Creek resulting from the 9 proposed structures under conditions of uniform rainfall was computed in the following manner. The terms "apparent runoff" or "Y2" as used in this appendix refer to the depth of runoff which would be required to produce a given flow after installation of the retarding structures. This expression is in recognition of the fact that there is no actual reduction in total runoff resulting from this part of the program.

Release flow was estimated at the average rate required to drain a full reservoir in 144 hours. To release the weighted value of 3.11 inches of detention storage in Mulberry Creek the average rate of discharge would be 918 second feet, or 13.9 second feet per square mile of drainage area above the structures. The depth of runoff required to create such stream discharge was determined to be 0.052 inches from the runoff-discharge (Y-Q) relationship established for Mulberry Creek. The release rate in some tributaries was estimated at the rate necessary to drain the reservoirs within 72 hours. The channel capacity of each stream below the structure sites was used as a guide in the selection of the release rate of discharge.

The determination of apparent runoff after installation of the recommended floodwater retarding structures was computed in the following manner (table 25).

Table 25. Runoff after installation of Floodwater Retarding Structures in Mulberry Creek.

Brazos River Watershed.

| Runoff before Installation of Structures, Y1 | Weighted Runoff from area with no Structures | Weighted Apparent Runoff from Area with Structures Installed | Weighted Apparent Runoff from Entire Area. |
|---|---|---|---|
| (inches) | (inches) | (inches) | (inches) |
| 0.1 | .72 x 0.1 | .28 x 0 + 0.028 1/ | 0.100 |
| 1.0 | .72 x 1.0 | .28 x 0 + 0.052 | 0.772 |
| 3.11 2/ | .72 x 3.11 | .28 x 0 + 0.052 | 2.291 |
| 5.0 | .72 x 5.0 | .28 x 1.89 +0.052 | 4.181 |
| 7.0 | .72 x 7.0 | .28 x 3.89 + 0.052 | 6.181 |

1/ Capacity of release tube not fully utilized by 0.1 inch of runoff
2/ Storage capacity at spillway level.

Several depths of runoff, including the value representing the average retarding capacity of the reservoirs, were selected for use in computation of an average curve of weighted runoff. Each value of runoff was multiplied by the fractional part of the sample area not affected by structures. To this product was added the product obtained by multiplying the fractional part of the area affected by the installations by the difference between depth of runoff and the floodwater retarding capacity, 3.11 -inches for the Mulberry Creek structures. The release flow in terms of depth of runoff from the entire sample was added to the two preceding determinations to obtain the computed weighted sample tributary runoff after installation of the structures for the initial amount of runoff considered. These points when plotted gave the Y1-Y2 curve shown in figure 16.

This curve was used with the values of runoff remaining after application of the conservation measures on the tributary. These computations were set up as shown in table 22.

Reduced runoff resulting from floodwater retarding structures on the main streams of subwatersheds was computed by expansion, on a weighted basis, of the reduced runoff determined in each sample tributary similar to the area in the watershed. This was accomplished by multiplying the reduced runoff, Y2 (in a sample area) for selected amounts of runoff, by a number representing the fractional part of the subwatershed similar to the sample. A field survey was made of those parts of tributaries considered dissimilar to sample tributaries and this information was used with the values obtained by proration from the sample tributary areas. To include the full effect of the structures in each subwatershed, computations were made for each depth of runoff representing structure capacity at spillway elevation in each sample tributary used. The totals of these weighted values of reduced runoff were then plotted opposite the unreduced runoff to derive a curve for the subwatershed similar to figure 16 for Mulberry Creek.

In the use of the method outlined in the foregoing, reductions because of retarding structures were computed only on streams below the structures. No reductions were computed on short drainage areas draining directly into large streams and in areas too flat to afford structure sites. The recommended program includes floodwater retarding structures only in those tributaries in which this type of construction appears to be economical at the present time.

Provision was made for a permanent pool in those reservoirs having adequate capacity for both retarding and sediment storage. The determination of the capacity required for sediment storage was made using an average sediment production rate applicable to the conservation problem area in which the structure would be located. These rates were 2.0 acre-feet per year per square mile of drainage area in Blackland Prairie, 0.5 acre-foot in Grand Prairie, and 1.0 acre-foot in the Forested Coastal Plain, Cross Timbers, Reddish Prairie and Rolling Red Plains. Storage capacity for a 50-year period of sediment production at the rate selected was estimated. It is expected that the loss of retarding storage capacity in reservoirs not having permanent pools, about 30 percent of the number recommended, would be negligible because of the temporary nature of the pond. Structures would not be built below areas contributing large amounts of bedload material until remedial measures reduce the sediment contribution to an acceptable rate. No permanent pool was included in the estimates of those structures in the Blackland Prairie, if the required pool would have a surface area exceeding 50 acres, because of the value of land. These structures constitute about 8 percent of those planned. The estimates made do not include any allowance for storage volume resulting from borrow made for construction of the embankment. As much of this material as possible will be taken from the reservoir area to provide additional capacity and stockwater.

Table 26 gives general data regarding size, number, and distribution of the recommended floodwater retarding structures. At this stage of planning no designs have been made and quantities and costs were estimated on the following bases.

Dams will be constructed of rolled earth fills provided with automatic draw-down structures designed to empty the full reservoirs in from 72 to 144 hours. The service spillway, of sufficient capacity to handle the discharge from a 50-year frequency storm after reductions in the reservoir, will be constructed of sod or concrete depending on the characteristics of each site. An emergency type spillway, or additional operating head on the service spillway, will be provided for discharges greater than those from the 50-year frequency storm. Careful study of hazard to life and property will be made for each site used.

Table 26. Proposed Floodwater Retarding Structures

Brazos River Watershed

| Subwatershed | | Size | Structures Recommended | Average Drainage Area | Average Detention Storage | | Average Surface at Side Spillway Elevation | Sub-Watershed above Structures | Structures with Sediment Storage |
|---|---|---|---|---|---|---|---|---|---|
| (no.) | (name) | (sq.mi.) | (no.) | (sq.mi.) | (ac.ft.) | (inches) | (acres) | (percent) | (no.) |
| 10 | Possum Kingdom to Whitney 1/ | 2,168 | 9 | 5.5 | 882 | 3.71 | 115 | 2.3 | 9 |
| 12 | Paluxy Creek | 432 | 15 | 7.8 | 948 | 3.05 | 116 | 27.1 | 15 |
| 14 | Aquilla Creek | 417 | 30 | 5.5 | 1,018 | 3.45 | 103 | 39.6 | 0 |
| 15 | Bosque River 1/ | 1,676 | 61 | 9.0 | 1,180 | 1.70 | 119 | 33.0 | 57 |
| 16 | Whitney to Waco 1/ | 280 | 3 | 3.2 | 660 | 4.00 | 58 | 3.4 | 3 |
| 17 | Waco to Little River | 1,495 | 82 | 6.1 | 1,169 | 3.57 | 377 | 33.6 | 37 |
| 18 | Little River | 7,373 | 287 | 8.7 | 930 | 2.00 | 158 | 33.9 | 287 |
| 19 | Little Brazos | 658 | 29 | 9.1 | 1,760 | 3.63 | 152 | 40.1 | 25 |
| 20 | Navasota River 1/ | 1,782 | 27 | 3.2 | 660 | 4.00 | 58 | 4.8 | 27 |
| 22 | Yegua River 1/ | 1,012 | 12 | 11.0 | 1,693 | 2.89 | 261 | 13.0 | 8 |
| | Brazos River Watershed | 17,293 | 555 | 7.9 | 1,043 | 2.55 | 178 | 25.3 | 468 |

1/ Structures not recommended throughout entire watershed.

# APPENDIX IV

## WATERSHED FLOOD PROBLEMS AND RELATED DAMAGES

## DESCRIPTION OF FLOOD DAMAGES

Floods may be caused by either general storms or thunderstorms. The general storms originate either in the Gulf of Mexico or in the Southwestern Highlands and travel into the watershed. They usually cover a large portion of the watershed and may cause widespread flooding. The thunderstorms are often characterized by intense precipitation over comparatively small areas.

### Floodwater Damages

Three general types of floods may result from the two storm patterns: (1) floods on the smaller tributaries having little effect on the main streams, (2) minor floods on the main streams, and (3) major floods on the main streams. Floods on the tributaries and minor floods often result in damage to crops, some loss of livestock, damage to fences and some damage to buildings, roads and other property. Major floods differ from minor floods in degree and extent and cause greater damage.

The social and economic problems arising from floods in the Brazos River Watershed result largely from the flooding of agricultural lands. The non-agricultural types of flood damage on this watershed do not constitute as large a percentage of the total damage as in watersheds where industrial development in the flood plains has been extensive. Economic and social problems closely related to agricultural flood damages include direct income losses to farm operators, damage to flood plain lands, loss to local businesses, fears associated with possible future floods and indirect losses which may occur due to the decline in property values and community services. The general location of flood damages is shown in figure 23.

Floods in the Brazos River Watershed occur most frequently in April, May and June at which time serious damage may be done to growing crops or complete loss of mature small grain crops may occur. Fall floods are next highest in frequency of occurrence and may cause damage to mature crops. Floods occurring during the winter usually cause less damage to crops than is caused by floods in other seasons.

Without watershed treatment flooding can be expected to increase in frequency of occurrence, magnitude and severity of damage. This will be caused by deterioration of land cover, increased erosion and runoff and continued sedimentation of channels and flood plains.


Figure 23

LOCATION OF ANNUAL FLOOD AND SEDIMENT DAMAGES
BRAZOS RIVER WATERSHED - TEXAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H H BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P MERRILL

4-R-7245-27

Reservoir Sedimentation

Existing reservoirs: There are at least 40 reservoirs in the Brazos River Watershed, with original capacities ranging from a few hundred acre-feet to 730,000 acre-feet. Detailed sedimentation surveys have been made on a few of these reservoirs, and reconnaissance measurements taken on 11 others. The known reservoirs and available pertinent data are listed in table 27.

Very few of the reservoirs are located in the High Plains at the upper end of the watershed or in the Blackland Prairie and Forested Coastal Plains areas of the lower portion. Reservoirs are most abundant in the Redbed Plains (Rolling Red Plains) and Palo Pinto sections, decreasing in number downstream from these sections. The majority of them serve as municipal water supplies, four are recreational lakes, and Possum Kingdom Lake (the largest in the basin) furnished hydro-electric power. Their original capacities represent nearly 1 million acre-feet of water storage. The costs of all reservoirs are not known, but the total cost is estimated at about 16½ million dollars.

Three detailed surveys have been made on Lake Waco. These show a present sediment deposition rate of 0.49 acre-foot annually per square mile of drainage area, with an additional 0.19 acre-foot passing through the lake. A reconnaissance survey of Possum Kingdom Lake 1/ showed that it receives about 0.5 acre-foot of sediment per square mile of drainage area annually from its watershed which includes High Plains, Redbeds Plains and Palo Pinto sections. Lake Abilene, located in the Callahan Divide, receives only 0.2 acre-foot of sediment per square mile of drainage area annually.

The total annual sediment deposition in reservoirs which have been investigated is 8,550 acre-feet. Their total original capacity was 830,000 acre-feet, and total investment $13,000,000. The value of the annual capacity loss due to sediment deposition amounts to $149,300, based on the cost of each reservoir per acre-foot of storage capacity. If the reservoirs not investigated are trapping sediment at a rate proportionate to the above, they are receiving 1,750 acre-feet of sediment annually and if the average cost per acre-foot of storage is $40, the annual damage amounts to $70,000. On this basis, sediment deposited in reservoirs in the Brazos River Watershed is causing an annual damage of $219,300 due to decreases in effective storage capacities.

Predictions of sedimentation in proposed reservoirs: The Corps of Engineers plan of improvement for the Brazos River Watershed includes two reservoir projects which have been authorized and are under construction and six reservoir projects which have been recommended.

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1/ Field Survey, 1949.

Table 27

Reservoirs in the Brazos River Watershed

| | Name | Location (Nearest City) | Stream | Ownership & Purpose of Reservoir 3/ | Date Completed | Original Capacity | Annual Depletion of Storage | Drainage Area | Physiographic Province (Physical Land Unit) 2/ | Original Storage per Sq. Mi. of Drainage | Annual Sediment Accumulation Per Sq. Mi. of Drainage | Original Cost | Class of Data | Source of Data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Ac. ft.) | (Percent) | (Sq.Mi.) | | (Ac. ft.) | (Ac. ft.) | (dollars) | | |
| | **Major Reservoirs** | | | | | | | | | | | | | |
| 1 | Lake Ft. Phantom Hill | Abilene (12 Mi. NE) | Elm Creek | City of Abilene, MWS | 1939 | 70,000 | | 482 | RR-80%; EP-20% | 145 | | | File Information | USCS Circular 23, March 1948 |
| 2 | Lake Cisco | Cisco (4 Mi. N) | Sandy Creek | City of Cisco, MWS | 1923 | 31,250 | | 23 | HP | 1,359 | | 2,000,000 | File Information | Freese & Nichols, Consulting Engineers |
| 3 | Possum Kingdom Lake | Graford | Brazos River | Brazos R. Cons. & Rec. District, P, FC, R | 1941 | 729,985 | 1.0 | 14,098 | HP-5%; RR-50%; RP-45% | 51.8 | 0.5 | 8,654,706 | Reconnaissance | Rogers & Party, 1949 |
| 4 | Lake Waco | Waco (4 mi. W) | Bosque River | City of Waco, MWS | 1930 | 39,378 | 2.06 | 1,666 | GP-80%; CT-16%; RR-4% | 23.6 | 0.49 | 2,000,000 | Detailed Survey | Surveys in 1935, 1936, and 1947. (Rates are for period 1936-47) |
| | **Minor Reservoirs** | | | | | | | | | | | | | |
| 1 | Buffalo Lake No. 1 | Lubbock (9 Mi. SE) | Double Mt. Fk. | W. R. Rodgers, R | 1937 | 280 | | 90/ | HP | | | | Owner Estimate | W. R. Rodgers, Owner |
| 2 | Buffalo Lake No. 2 | Lubbock (9 Mi. SE) | Double Mt. Fk. | W. R. Rodgers, R | 1938 | | | 90/ | HP | | | | Owner Estimate | W. R. Rodgers, Owner |
| 3 | Two Draw Lake | Post (1 Mi. N) | Rattlesnake Creek | Double U. Co., R | 1910 | | | 3 | HP | | | | Owner Estimate | Double U. Co. |
| 4 | Lake Trammel | Sweetwater (6 Mi. S) | Sweetwater Cr. | City of Sweetwater MWS | 1916 | 3,161 | 0.5 | 55 | EP-70%; RR-30% | 57 | 0.26 | 335,000 | Contour Survey | Capacity measured by Freese & Nichols, 1948 |
| 5 | Lake Sweetwater | Sweetwater (7 Mi. SE) | Bitter Creek | City of Sweetwater MWS | 1930 | 13,810 | 0.3 | 110 | EP-70%; RR-30% | 126 | 0.4 | 462,000 | Reconnaissance | Jones & Swigart, 1941 |
| 6 | Railroad Lake | Sweetwater | Kildoogan | G. C. & S. F. Ry. I | 1910 | 890 | | 51 | HP-80%; RR-20% | 17 | | | File Information | Freese & Nichols, Rep. 343 acre-feet Capacity 1947 |
| 7 | Lake Abilene | Abilene (19 Mi. SW) | Elm Creek | City of Abilene, MWS | 1921 | 10,325 | 0.19 | 98.5 | EP-50%; RR-50% | 104.8 | 0.21 | 225,000 | Detailed Survey | Survey in September 1948 |
| 8 | Upper Lake | Hamlin (2 Mi. W) | Calif. Creek | City of Hamlin, MWS | 1917 | 510 | 0.9 | 32 | RR | 16 | 0.15 | 31,400 | Reconnaissance | Jones & Swigart, 1941 |
| 9 | Moore Lake | Hamlin (2 Mi. W) | Calif. Creek | City of Hamlin, MWS | 1909 | | | 32 | RR | | | 5,000 | | |
| 10 | New Hamlin Reservoir | Hamlin (4 Mi. S) | Dry Calif. Cr. | City of Hamlin, MWS | 1939 | 2,460 | | 36 | RR | 68 | | 235,000 | Consultant's Plans | Freese & Nichols, Consulting Engineers |
| 11 | Lake Fenick | Lueders | Clear Fk. Brazos River | City of Stamford, MWS | 1920 | 3,096 | 4.5 | 2,250 | RR-60%; HP-20%; EP-20% | 1.4 | 0.06 | | | From USDA Tech. Bull. 524, 1936 |
| 12 | Anson City Reservoir | Anson (4 Mi. E) | Redmud Creek | City of Anson, MWS | 1941 | 1,250 | | 36 | RR | 35 | | | Consultant's Plans | Freese & Nichols, Consulting Engineers |
| 13 | Lake Lytle | Abilene (1 Mi. SE) | Lytle Creek | W. Texas Utilities, I | 1909 | | | 64 | RP-80%; EP-20% | | | | File Information | Freese & Nichols, Consulting Engineers |
| 14 | Lake Kirby | Abilene (3 Mi. S) | Cedar Creek | City of Abilene, MWS | 1928 | 8,133 | 0.5 | 44 | RP-80%; EP-20% | 185 | 0.94 | 200,000 | Reconnaissance | Jones & Swigart, 1941 |
| 15 | Lake Diller | Albany (NW) | N. Hubbard Cr. | City of Albany, MWS | 1913 | 400 | 0.3 | 8.3 | RR | 48 | 0.18 | | Reconnaissance | Jones & Swigart, 1941 |
| 16 | Delafosse Lake | Albany (12 Mi. E) | Dry Branch | Geo. Delafosse, I | 1918 | | | 11.2 | HP | | | | Estimate | Mr. C. A. Scottie |
| 17 | Lake McCarty | Albany (6 Mi. SW) | Salt Fr Hubbard C. | City of Albany, MWS | 1942 | 2,800 | | 44 | RR | 64 | | | Consultant's Plans | Freese & Nichols, Consulting Engineers |
| 18 | Throckmorton City Res. | Throckmorton (1 Mi.W) | - | City of Throckmorton, MWS | 1941 | 1,650 | | 9.6 | RR | 172 | | | Consultant's Plans | Freese & Nichols, Consulting Engineers |
| 19 | Tucker Lake | Strawn (5 Mi. W) | Russell Creek | City of Strawn, MWS | 1937 | 1,600 | | 4.7 | RP | 340 | | 123,000 | File Information | City Secretary of Strawn, Texas |
| 20 | Lake Daniel | Breckenridge (7 Mi. S) | Gonzales Cr. | City of Breckenridge MWS | 1939 | 10,000 | | 115 | HP | 87 | | 231,700 | Consultant's Plans | Freese & Nichols, Consulting Engineers |
| 21 | Lake Hagaman | Ranger (2 Mi. NE) | N. Palo Pinto Creek | Hagaman Estate, MWS | 1913 | 1,158 | | 2.5 | RP | 463 | | | Owner Estimate | Leslie M. Hagaman |
| 22 | Lake Eastland | Eastland (1 Mi. NW) | N.Fk.Leon R. | City of Eastland, MWS | 1920 | 6,125 | 0.4 | 32 | RP | 191 | 0.71 | 212,300 | Reconnaissance | Jones & Swigart, 1341 |
| 23 | Lake Leon | Eastland (2 Mi. E) | Leon River | Tex. Elec. Ser. Co., I | 1920 | 1,637 | 1.1 | 225 | RP-60%; EP-40% | 7 | 0.08 | | Reconnaissance | Jones & Swigart, 1941 |
| 24 | Lake Eddleman | Graham (2 Mi. N) | Flint Creek | City of Graham, MWS | 1929 | 6,500 | 0.5 | 42 | HP | 155 | 0.82 | 212,600 | Reconnaissance | Jones & Swigart, 1941 |
| 25 | Lake Mineral Wells | Mineral Wells(5 Mi. E) | Rock Creek | City of Mineral Wells, MWS | 1922 | 10,741 | 0.8 | 74.4 | CT-70%; HP-30% | 87 | 1.18 | 573,000 | Reconnaissance | Jones & Swigart, 1941 |
| 26 | Lake Eanes | Comanche (2 Mi. SW) | Mercer Creek | City of Comanche, MWS | 1926 | 1,313 | 0.35 | 13.8 | GP | 95.4 | 0.33 | 123,000 | Detailed Survey | Survey in September, 1946 |
| 27 | Lake Comanche | Comanche (5 Mi. S) | Mercer Creek | City of Comanche, MWS | 1949 | 4,800 | | 35 | GP-80%; CT-20% | 137 | | 232,262 | Consultant's Plans | Freese & Nichols, Consulting Engineers |
| 28 | Meridian Lake | Meridian (3 Mi. SW) | Bee Creek | Tex.State Parks Bd., R | 1934 | 723 | 0.3 | 3.3 | GP | 226 | 0.70 | | Reconnaissance | Rogers, 1948 |
| 29 | Hamilton City Lake | Hamilton (2 Mi. E) | Two Mile Creek | City of Hamilton, MWS | 1923 | 538 | 0.5 | 12 | GP | 45 | 0.21 | 90,000 | Reconnaissance | Jones & Swigart, 1941 |
| 30 | Lake Ft. Parker | Groesbeck (5 Mi. N) | Navasota River | Tex.State Parks Bd., R | | | | 270 | BL-70%; FC-30% | | | | File Information | Texas State Parks Board |
| 31 | City Lake | Marlin (2-1/2 Mi. NE) | Big Sandy Creek | City of Marlin, MWS | 1923 | 1,535 | 1.5 | 18 | BL | 85 | 1.27 | | Consultant's Plans | Water Superintendent, Marlin, Texas |
| 32 | New City Lake | Marlin (2 Mi. E) | Big Sandy Creek | City of Marlin, MWS | 1949 | 3,070 | | 22 | BL | 140 | | 350,000 | File Plans | Water Superintendent, Marlin, Texas |
| 33 | Lake Rogers | Rogers (4 Mi. SW) | - | City of Rogers, MWS | 1922 | 164 | 1.9 | 0.55 | BL | 298 | 6.08 | | Detailed Survey | Survey in September, 1934 |
| 34 | Normangee State Pk. Lake | Normangee (6 Mi. W) | Spring Branch | City of Normangee, R | 1935 | | | 2 | FC | | | | File Plans | Texas State Parks Board |
| 35 | Camp Creek Lake | Franklin (12 Mi. E) | Camp Creek | Camp Cr. Wtr. Co., R | 1949 | 8,400 | | 40 | FC | 240 | | | File Plans | Love Abstract Company, Franklin, Texas |
| 36 | Dan George Lake | Richmond (10 Mi. SE) | Dutch John Cr. | A. P. George, R | 1910 | | | | CO | | | | Owner Estimate | A. P. George, Owner |

1/ Abbreviations: HP-High Plains; RR-Rolling Red Plains; EP-Edwards Plateau; CT-Cross Timbers; GP-Grand Prairie; BL-Blackland Prairie; FC-Forested Coastal Plain; RP-Reddish Prairie; CO-Coast Prairie

2/ Most of the High Plains do not contribute to downstream runoff.

3/ Reservoir purpose abbreviations: MWS-Municipal Water Supply; I -Industrial; P -Power; FC -Flood Control; R -Recreation

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Table 28 lists pertinent data on these reservoirs, estimated rates of sediment contribution to them, and the expected reduction in sedimentation rates if the recommended program is put into effect. The estimates of sedimentation rates were based on one or more of the following: comparison with records of reservoir surveys in similar areas; average sediment load of stream on which reservoir site is located (if suspended sediment records were available); sediment contribution rates of conservation problem areas determined from reservoir surveys.

Examples of methods used to estimate sedimentation rates in reservoirs appear below.

1. Lampasas Reservoir: Lake Eanes and Medina Lake, with similar watersheds, have received sediment at rates of 0.33 and 0.45 acre-feet annually per square mile of drainage. The average is 0.39. Annual sediment deposit in Lampasas Reservoir is predicted to be 0.40 acre-foot per square mile of drainage.

2. Lanesport Reservoir: About 40 percent of the watershed is in the Blackland Prairie and 60 percent in the Grand Prairie. Approximate annual sediment production rates per square mile of drainage:

| | |
|---|---|
| Blackland Prairie | 3.0 acre-feet |
| Grand Prairie | 0.4 acre-foot |

The average is $(3.0 \times .40) + (0.4 \times .60) = 1.44$
Predicted annual sediment deposit in Lanesport Reservoir, 1.50 acre-feet per square mile of drainage.

3. Ferguson Reservoir on the Navasota River: No reservoir survey data in a comparable area is available on which to base sediment production rates. A suspended sediment sampling station on the Navasota at Easterly determined the average sediment content of the water to be 0.071 percent by weight for the period of record, and the average stream flow to be 433,650 acre-feet per year. Sediment content in acre-feet is

$$\frac{433{,}650 \times 1361\ 1/ \times 0.00071}{1307\ 2/} = 321$$

The drainage area at the gage is 949 square miles, so the sediment contribution per square mile of drainage is 321 ÷ 949 or 0.34 acre-foot per year. Predicted rate for Ferguson Reservoir, 0.35 acre-foot of sediment annually per square mile of drainage.

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1/ Tons of water per acre-foot.
2/ Weight in tons of one acre-foot of sediment at 60# per cu. ft.

Table 28. Estimates of Sedimentation Rates in Proposed Reservoirs

Brazos River Watershed

| Reservoir | Location, Stream | Capacity: Top of Power or Conservation Pool | Capacity: Top of Flood Control Pool | Drainage Area | Original Cost | Predicted Sedimentation Rates — Under Present Conditions: Sediment Output per sq. mi. of Drainage | Under Present Conditions: Sediment Deposit in Reservoir | Under Present Conditions: Capacity Loss in Sediment & Cons. Pool | Under Present Conditions: Life of Sediment & Cons. Pool | With Recommended Program: Reduction in Sediment | With Recommended Program: Life of Sediment & Cons. Pool |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Ac.-ft.) | (Ac.-ft.) | (Sq.Mi.) | (Thousands Dollars) | (Ac.-ft./Year) | (Ac.-ft./Year) | (Percent/Year) | (Years) | (Percent) | (Years) |
| Whitney 1/ | Brazos R. | 642,200 | 2,017,500 | 3,558 2/ | 32,660 | 0.60 | 2,235 4/ | 0.3 | 287 | 50 | 575 |
| Belton 1 | Leon R. | 459,500 | 1,094,400 | 2,190 3/ | 22,361 | 0.40 | 912 5/ | 0.2 | 504 | 30 | 720 |
| Waco | Bosque R. | 170,000 | 658,000 | 1,670 | 26,879 | 0.61 | 1,024 | 0.6 | 166 | 50 | 232 |
| Proctor | Upper Leon | 64,100 | 320,700 | 1,225 | 11,281 | 1.50 | 1,837 | 2.9 | 35 | 60 | 87 |
| Lampasas | Lampasas R. | 91,100 | 481,000 | 1,321 | 17,265 | 0.40 | 528 | 0.6 | 173 | 30 | 246 |
| Lanesport | San Gabriel | 45,000 | 281,100 | 711 | 16,043 | 1.50 | 1,066 | 2.4 | 42 | 50 | 72 |
| Somerville | Yegua Creek | 64,700 | 390,700 | 1,012 | 8,331 | 0.35 | 354 | 0.5 | 183 | 25 | 244 |
| Ferguson | Navasota R. | 102,800 | 619,200 | 1,782 | 12,116 | 0.35 | 624 | 0.6 | 165 | 25 | 220 |

1/ Reservoir authorized and under construction.
2/ Excluding drainage area of 14,098 square miles above Possum Kingdom Lake.
3/ Excluding drainage area of 1,225 square miles above proposed Proctor Reservoir.
4/ Including 100 acre-feet of sediment estimated to pass through Possum Kingdom Lake.
5/ Including 35 acre-feet of sediment estimated to pass through proposed Proctor Reservoir.

Estimates of reduction in the rates of sediment contribution to the reservoirs with the recommended program range from 25 to 60 percent. They are based chiefly upon indications of reductions in sediment output between surveys of reservoirs, where some part of a conservation program had been applied. The latest survey of Lake Waco, for example, showed a reduction of more than 30 percent in rate of sediment contribution from the drainage area from a conservation program covering less than one-third of the area, and this program did not include measures specifically for flood control.

The estimated reductions are low (30 percent) in areas, such as the Lampasas Cut Plain, where present erosion is not greatly accelerated above a natural rate and where range land now predominates. They are high in areas such as the Blackland Prairie and West Cross Timbers where modern erosion is greatly accelerated.

Valley Sedimentation and Scour

High Plains and Plains Border: Erosion and sediment output rates in the greater part of the High Plains are generally low because of the nearly flat topography, low rainfall, and the absence of well-developed drainage. This applies to the 2,673 square miles in New Mexico (outside of the authorized survey area) as well as to about 6,000 square miles of level upland in Texas.

The High Plains Border, however, is a zone of active natural erosion. It occupies a belt from 5 to 15 miles wide extending generally northeasterly through Garza, Crosby, and Dickens Counties. Canyons and gullies have been cut through the sandy Ogallala formation across the face of the escarpment, and large quantities of sandy sediment have been transported from the High Plains Border into valleys of the Redbeds Plains below.

All valleys extending eastward from the edge of the High Plains have large deposits of sand, which are believed to be residual deposits from long-continued erosion of the High Plains Border. This sand deposit extends from 10 to 30 miles in the various valleys such as White River, Duck Creek, and Double Mountain Fork. These reaches are characterized by shifting channels and dune formation, but these conditions are not regarded as accelerated above a normal rate. Since most of the area in these valleys is low grade grazing land, damages by accelerated deposition are negligible (table 29).

Flood plain scour and stream-bank erosion are also negligible in the High Plains and High Plains Border areas. Some dune formation occurs in the valleys in the High Plains Border area, but most of it is confined to relatively narrow belts of low-value pasture along the channels and damages are negligible.

Table 29. Summary of Damages to Valley Lands by Sedimentation, Flood Scour, and Stream-bank Erosion

Brazos River Watershed

| Physiographic Subdivision | Annual Damage by Accelerated Deposition | | Annual Damage by Flood-plain scour | | Annual Damage by Stream-bank Erosion | | Accessory Damage |
|---|---|---|---|---|---|---|---|
| | (acres) | (percent) | (acres) | (percent) | (acres) | (percent) | |
| High Plains and Plains Border | N 1/ | N | N | N | N | N | Some sand dune formation |
| Redbeds Plains (Rolling Red Plains) | 200 | 50 | 200 | 50 | 250 | 100 | Some sand dune formation |
| Palo Pinto Section (Reddish Prairie) | N | N | 300 | 50 | N | N | Some accelerated deposition in minor valleys |
| Edwards Plateau, Lampasas Cut Plain and Grand Prairie | N | N | N | N | N | N | Local gravel bars overbank |
| West Cross Timbers | 200<br>45 | 50<br>25 | N | N | N | N | Flood frequencies doubled |
| Black Prairie (Blackland Prairie) | 550<br>550 | 50<br>75 | 1300 | 50 | N | N | Flood frequencies doubled |
| Forested Coastal Plain | 600 | 25 | N | N | N | N | |
| Coastal Prairies | N | N | N | N | N | N | |

1/ N - negligible

The chief sediment sources in the High Plains and in valleys immediately eastward are slow erosion of sandy sediment in the bordering canyons and of sandy deposits in the valleys below the escarpment. The output from both of these sources is small and is believed to be virtually a normal rate.

Redbeds Plains: The Redbeds Plains (Rolling Red Plains) section of the Brazos River Watershed is a large area (8,522 sq. mi.) including outcrop belts of the Dockum formation of Triassic age and the Redbed series of Permian age. Much of this section is subject to accelerated erosion, and it is a major sediment source in the Brazos River Watershed. In the western part of this section outliers of loose sandy deposits of Quaternary age contribute locally to valley deposition. Along the southern margin of the basin (Scurry, Nolan, and Taylor counties) erosion of the Redbeds is limited by resistant caps of cretaceous limestones.

Clear Fork and its tributaries have suffered relatively unimportant damages by overbank deposition of sediment. In Clear Fork Valley such damages are negligible. In a number of smaller tributaries, especially above Lake Abilene, and in small valleys in Fisher County, however, the channels are filled with sandy sediment, and some overbank deposition has occurred. Altogether it is estimated that a total area of about 50 acres per year of pasture land in such tributaries is suffering 50 percent damage per year.

The main valley of the Brazos River above Graham and its two major tributaries above Haskell County, however, have sustained more serious damage by overbank deposition. From reconnaissance examinations of these three valleys it is estimated that an average of 0.5 acre per mile is reduced 50 percent in productivity annually in a total of 200 miles of valley length. This is a 50 percent damage to 100 acres annually. Another 50 acres in the various smaller tributaries of the three streams suffer similar damage. The total estimated damage in the Redbeds Plains section, including Clear Fork, is 50 percent damage to 200 acres of bottomland annually.

In the drainage area of Clear Fork and its tributaries, flood plain scour and stream-bank erosion are negligible. Channels, in general are relatively large and stable, and sediment has not accumulated in them to any great extent. Bank cutting, however, is causing total destruction of an average area of approximately 1.0 acre per mile annually in a total valley length of 250 miles along the Brazos River, Salt Fork, and Double Mountain Fork above Graham. Any recovery of use of such land is unlikely, since the accretion deposits on insides of bends become sandy wastes. Therefore, an estimated total of 250 acres of land in the Redbeds Plains is destroyed annually by bank erosion.

Flood plain scour is causing some damage in the Brazos River valley above Graham, and in the valleys of Salt Fork and Double Mountain Fork.

In a total valley length of 200 miles in the main Brazos River system above Graham reconnaissance surveys have indicated that an average annual damage of 50 percent decrease in productivity on 1.0 acre per mile of valley is caused by flood plain scour. Hence 200 acres per year suffer a reduction of 50 percent in utility by this process in the Redbeds Plains section of the drainage area. Recovery rates of scoured areas are slow.

Estimates of main sediment sources have been made following inspection of all main valleys and major upland areas. It is estimated that 50 percent of the sediment transported by the main streams, Brazos River above Graham, Salt Fork and Double Mountain Fork, is derived by bank erosion and 50 percent is carried into the main valleys by tributaries. Of the sediment delivered by tributaries it is estimated that 75 percent is derived on upland areas by gully development, and 25 percent by sheet erosion. Clear Fork, which has relatively stable banks, derives little sediment by bank erosion. It is estimated that its tributaries, which drain areas of relatively resistant rocks, derive 25 percent of their sediment by gully development, and 75 percent by sheet erosion.

Palo Pinto Section: The amounts of damage by accelerated sedimentation are relatively low in the Palo Pinto section (Reddish Prairie). Because of sharply contrasting differences in types of soils and resistance of underlying formations, local conditions vary widely in the tributary valleys. In the main Brazos River valley sedimentation and scour damages are limited by high terraces of considerable extent which lie above flood levels.

In the main valley of the Brazos River, from the east boundary of Throckmorton County to the west boundary of Parker County, accelerated deposition on valley lands is negligible. A reach of valley about 65 miles long between Graham and Graford is occupied by Possum Kingdom Reservoir which affects flood flows below. Some tributaries in this section, such as Big Sandy and Big Cedar Creeks, have scattered deposits of modern sandy sediment on their valleys, but in most places the deposit is not sufficiently widespread nor coarse enough to cause measurable damage.

Scour of flood plains occurs in a few localities in the Brazos River and Clear Fork valleys above Graham and along a few of the larger tributaries of the Palo Pinto section, but it is believed to be accelerated little above a normal rate. In a total valley length of approximately 300 miles of the Brazos River (excluding Possum Kingdom Reservoir) the estimated damages by flood plain scour are 50 percent damage to 0.5 acre annually per valley mile, or 50 percent reduction in productivity on 150 acres of valley land annually.

Damages by stream bank erosion in the Palo Pinto section are negligible.

Sheet erosion is the most important agency of erosion and it is estimated that 75 percent of the sediment carried to main streams originates by this process. Locally, especially in sandy areas, gully development is important.

Edwards Plateau, Lampasas Cut Plain, and Grand Prairie: These three sections are grouped in the evaluation of sedimentation and valley erosion damage because they are all underlain by relatively resistant cretaceous limestone formations (figure 2). Together they occupy about 9,000 square miles in the central part of the Brazos River Watershed. Rates of erosion and sediment output in general are low. Damages by accelerated deposition are slight, and channels of most streams are stable and have relatively large capacities. The valley bottoms generally slope strongly toward the channels, and the channels are incising into limestone and shale formations. The chief types of sediment are gravels, which form bars in the channels, and silt and clay which travels long distances downstream with every flood.

Damages by accelerated deposition, flood plain scour, and bank erosion are negligible.

West Cross Timbers: In the Brazos River Watershed the Cross Timbers area lies chiefly within the western parts of Parker, Hood, Erath, and Comanche counties. This belt has sandy soils underlain by unconsolidated, easily eroded Trinity sands of Lower Cretaceous age. Accelerated erosion, and especially gully development, is serious, and practically all valleys in the section have suffered some degree of damage by accelerated deposition of sandy sediment. Fertile valley soils have been buried beneath sand deposits, channels have been filled, and damages to roads and bridges have been extensive.

Rapid, modern deposition of sandy deposits has caused a decrease in productivity of 50 percent to a total area of 11,500 acres in 60 years in tributary valleys and flood frequencies have been approximately doubled. An additional area of 2,700 acres in the same valleys has sustained 25 percent damage in the 60-year period.

Scour of flood plains and bank erosion in the larger tributary valleys are negligible, since deposition from eroded uplands is the predominant process.

It is estimated that gully development is responsible for 75 percent of the sediment carried into alluvial valleys in the Cross Timbers, and that 25 percent of the sediment originates by sheet erosion.

Blackland Prairie: The Blackland Prairie occupies an area of 4,600 square miles, and has the highest average rate of erosion in the drainage area under present land use. Rates of sediment contribution from drainage areas of a few square miles in extent range from 2.00 to more than 5.0 acre-feet per square mile annually. Practically all of the sediment, derived by erosion of the dark clay soils and underlying marls, chalks and clays, is clay and silt. Much of it travels long distances downstream

where it is deposited in reservoirs. This material in suspension causes high filtration costs for city water systems.

In the lower part of the San Gabriel River valley below Georgetown, 200 acres of land are damaged annually by sediment in quantities sufficient to bury growing crops. Deposition on densely vegetated channel banks has decreased channel capacities sufficiently to cause an estimated increase in flood frequency of 20 percent. In the Brushy Creek system below Hutto all of the bottomlands are characterized by partially or completely filled channels, heavy overbank deposition, swamps, intermittent scour, and substantially increased flood frequencies. The deposition of large bars of sediment, and the formation of intervening scour channels have produced a rough topography, and the thickness of the overbank deposits ranges from 2 to 10 feet. In the Brushy Creek system below Taylor, approximately 15,000 acres of bottomland have been reduced 75 percent in productivity in a period of 45 years.

In Blackland valleys north of Temple it is estimated that an additional area of 25,000 acres has suffered a 50 percent damage by accelerated deposition in 45 years. These valleys include Pond, Big, Aquilla, and Tehuacana Creeks as well as smaller tributaries and flood frequencies, on the average, have been doubled.

Stream bank erosion occurs locally in a number of tributary valleys but has not affected sufficiently large areas to permit economic evaluation.

Flood plain scour, however, has caused substantial damages in the larger tributary valleys where the streams are competent to transport the large loads of sediment delivered to them from upstream sources. Hence the scour damages generally occur downstream below the areas of heavy sedimentation damages in valleys such as Brushy Creek, San Gabriel River, Little Elm and Aquilla Creeks, and on the larger bottoms such as that of the Little River. In San Gabriel, Brushy Creek and Little Elm systems approximately 500 acres annually suffer a 50 percent damage by flood scour, in the Little River valley 100 acres, and in tributary valleys north of Temple, 700 acres. A partial recovery of productiveness occurs within a 5 to 10-year period on the scoured areas.

Severe erosion on cultivated areas of the Blackland Prairie is one of the major sources of sediment. It is estimated that an average of 70 percent of the sediment transported to downstream sites is derived from sheet erosion, and 30 percent from gully erosion. Locally, especially in the Taylor marl area (figure 2) these proportions are sometimes reversed.

Forested Coastal Plain: A great variety of soils and rock outcrops is characteristic of the Forested Coastal Plain. Most of the rock formations are poorly consolidated and the alternating belts of clays,

sands, and sandy clays extend across the main drainage lines. Erosion rates in many upland areas are high, and many small valleys receive deposits of sandy sediment. Several factors, however, limit the distance of downstream travel of much of the sediment. The high rainfall and humidity promote rapid growth of vegetation, and most of the small valley bottoms are choked with dense grass, trees or weeds. The larger valleys have low gradients and the slow current causes deposition of much sediment on upstream sites. Hence accelerated sediment deposition is not a problem on valley lands of streams such as the Navasota River, but it causes damages in valleys of a number of its tributaries. In a total length of 200 miles of tributary valleys of the Navasota River, it is estimated that 200 acres annually are reduced 25 percent in productivity by accelerated deposition of sandy sediment, and an additional 400 acres sustain similar damages in tributaries such as New Years and Yegua Creeks.

Scour channels are numerous in the Navasota River valley, but they occur chiefly on wooded land of relatively low value. Such channels are typical of mature valleys and are not judged to be representative of an accelerated condition.

Coast Prairie: Damages by deposition of sediment, flood scour, and bank erosion are not important in the Coast Prairie. It is an area of very low gradients, dense vegetation, and high humidity. The streams have sluggish flow and valleys are shallow.

## METHODS OF ESTIMATING FLOOD DAMAGES

### Area Included in Estimates

No damages, other than sedimentation of reservoirs, were calculated, nor corresponding benefits estimated in the areas to be inundated by the system of reservoirs recommended by the Corps of Engineers. No damages or benefits were estimated on the main stream of the Brazos and its tributaries from flood waters derived from streams above these installations. However, damages on joint flood plains of the Brazos and tributary streams, caused by flooding of the tributaries alone, were estimated and benefits from the recommended program were evaluated.

The areas on which damages were not calculated or were reduced from current rates and on which benefits were not estimated or were reduced were: (1) the lower portions of the Upper Leon, Cowhouse, Lampasas, and San Gabriel and the entire main streams of the Little River and the Lower Leon; 1/ (2) the Bosque River below the recommended Waco reservoir; 2/ (3) Yegua Creek below the recommended Somerville reservoir;

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1/ Appendix IV, Watershed Flood Problems and Related Damages, Interim Survey Report, Brazos River and Tributaries, Little River Watershed, USDA, 1950.

2/ Appendix IV, Watershed Flood Problems and Related Damages, Interim Survey Report, Brazos River and Tributaries, Bosque River Watershed, USDA, 1950.

(4) the Navasota River below the recommended Ferguson reservoir; and (5) the Brazos River below the Whitney Reservoir.

Estimation of Floodwater Damage

Floodwater damage, based on prices and values for 1948, was calculated in sufficient detail to permit estimation of future expected flood damage. The calculation included damage estimates both with and without the recommended program. Estimates of flood damage to crops, land, other agricultural property, and roads and bridges were based on an analysis of 198 damage schedules taken in the Little River Watershed, 103 in the Bosque River Watershed and 258 in the remainder of the Brazos River Watershed; a total of 559 in all.

Floodwater damages were calculated separately for: (1) reaches of the main streams, and (2) areas in subwatersheds typified by sample tributary watersheds and expanded to the appropriate subwatershed areas.

Crop and Grassland Damage: The flood damage to any cropland or grassland was computed through the following steps: (1) the difference between the value per acre of the undamaged crop and its value after flooding; (2) less the costs not incurred in growing or harvesting; (3) plus the costs of the extra cultivation caused by floods; or (4) plus the costs of all operations in producing an alternative crop of equal or lesser net value; and (5) less the gross value of the alternate crop. The dollars of net damage per acre were then divided by the original per acre undamaged value of the crop to determine a percent damage factor. For example, the percent flood damage to cotton flooded at a depth of 2.1-4.0 feet in April, May or June might be calculated as follows:

| | |
|---|---|
| Value of original crop | $64.94 per acre |
| Value of original crop after flood | 24.39 per acre |
| (1) Gross damage | $40.55 per acre |
| (2) Minus expenses saved (harvesting, ginning, etc.) | 13.50 per acre |
| | $27.05 per acre |
| (3) Plus added expense (extra cultivation) | 2.20 per acre |
| Net damage | $29.25 per acre |

The percent damage factor equals $29.25/$64.94 times 100, or 45 percent net flood damage. The percent flood damage to each crop was determined for seasons and depths of flooding by the method illustrated above and compiled in table 30. Except for damage to grassland, these percentages were applied in all subwatersheds of the Brazos River Watershed other than those of the Little and Bosque Rivers. Data on these two subwatersheds obtained in previous surveys were adjusted to 1948 price levels and combined with information from schedules in the Brazos

for this calculation of percent damage factors. The percent damage factors for grassland (table 30) were used in the parts of the Brazos River Watershed below the Whitney reservoir. These percentages were reduced progressively above Whitney until no damage to grassland from floodwater was calculated above the confluence of the Brazos River and the Clear Fork. The reduction in percent damage factors for grassland in areas upstream from the moist subhumid lower part of the watershed to the dry subhumid and semiarid upper sections corresponded to the farmers' estimates of damage to grassland by floodwater.

The major land uses of the flood plain were determined through data obtained from surveyed cross-sections and analysis of aerial photographs. The percentage of cultivated land occupied by each major crop was computed from field schedules. These schedules also supplied the information from which yields were estimated. From these data a composite damage rate per flooded acre was calculated for each season and depth of flooding in all sample tributaries as illustrated in tables 31 and 32. A composite flood plain acre was used because field investigations showed that variations in land use at different elevations of a given cross-section were not significant. For example, the area flooded by water 4 feet overbank at section 1 on Neil Creek was 31.5 percent cropland as compared with 30 percent for the entire flood plain of the sample tributary. A stream was divided into reaches, each with its individual land use, when significant differences were found in the land use along the length of the stream.

Original calculations of damageable values were based on 1948 prices. These were adjusted to 1949 prices by means of the "Index of prices received and paid by farmers for major product groups and for principal commodities, based on calendar year prices for selected periods" released by the Bureau of Agricultural Economics, April 1950. The indexes of individual commodities were weighted by the production of these products in each sample tributary. In areas in which no damage was calculated on pasture, the value of the pasture was not included in the weighting.

Flood Plain Scour Damage: The physical land damage due to scour was determined by reconnaissance in the stream valleys. Information on the average productivity of land in the flood plain was obtained from land owners and operators at the time flood damage schedules were taken.

It was determined that scour damage in the Brazos River Watershed at the present time occurs in about a ten year cycle from original damage to recovery, and that the amount of damage is not increasing but has reached a state of equilibrium.

The report of the damage appraisers listed the acreage damaged and the degree of damage. Thus, in the lower main stream area of Clear Fork, 30 acres of flood plain are damaged 50 percent by scour. The average production in this reach is about $10.00 per flood plain acre, therefore, the loss in production is $5.00 per year on 30 acres or

Table 30. Percent Damage to Crops and Grassland by Flood Depth Intervals and Seasons

Brazos River Watershed 1/

| Crop | Flood Depth (feet) | April, May June (percent) | July, Aug., Sept., Oct. (percent) | Nov., Dec., Jan., Feb., March (percent) |
|---|---|---|---|---|
| Cotton and Peanuts | 0-2.0 | 31 | 41 | 22 |
| | 2.1-4.0 | 45 | 55 | 30 |
| | 4.1-6.0 | 53 | 64 | 36 |
| | 6.1 & over | 56 | 65 | 38 |
| Corn | 0-2.0 | 37 | 35 | 7 |
| | 2.1-4.0 | 60 | 57 | 18 |
| | 4.1-6.0 | 65 | 72 | 31 |
| | 6.1 & over | 70 | 83 | 38 |
| Barley, Oats, and wheat | 0-2.0 | 47 | 7 | 5 |
| | 2.1-4.0 | 60 | 9 | 35 |
| | 4.1-6.0 | 69 | 10 | 50 |
| | 6.1 & over | 75 | 10 | 52 |
| Sorghum and meadow | 0-2.0 | 26 | 40 | 23 |
| | 2.1-4.0 | 37 | 63 | 26 |
| | 4.1-6.0 | 48 | 65 | 28 |
| | 6.1 & over | 52 | 68 | 29 |
| Grassland 2/ | All depths | 20 | 8 | 10 |

1/ Exclusive of Little and Bosque River Watersheds.

2/ Applies only to moist subhumid climatic area below Whitney reservoir.

Table 31. Composite Damageable Value of Crops and Pasture (1948 Prices) per Acre of Flood Plain
Mulberry Creek Sample Tributary

Brazos River Watershed

| Crop Use | Flood Plain in Each Use (percent) | Unit | Yield per Acre of Crop | Production per Acre of Flood Plain | Value per Unit (dollars) | Value of Production (dollars) |
|---|---|---|---|---|---|---|
| Cotton | 1.28 | lbs.of lint | 208 | 2.6624 | 0.3711 | 0.9880 |
| Wheat | 5.29 | bu. | 13 | 0.6877 | 1.97 | 1.3548 |
| Grain Sorghum | 2.55 | cwt. | 11.9 | 0.3034 | 1.94 | 0.5886 |
| Meadow | 0.18 | ton | 2 | 0.0036 | 17.80 | 0.0641 |
| Pasture | 81.38 | A.U.M. | 2 | 1.6276 | 1.38 | 2.2461 |
| Woods | 9.32 | - | - | - | - | - |

Table 32. Composite Crop and Pasture Damage Rate (1948 Prices) per Acre Flooded, by Season and Depth of Flooding, Mulberry Creek Sample Tributary

Brazos River Watershed

| Crop | Damageable Value Per Acre | Net Damage | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Depth: 0-2.0' | | Depth: 2.1-4.0' | | Depth: 4.1-6.0' | | Depth 6.1' & Over | |
| | | (percent) | (dollars) | (percent) | (dollars) | (percent) | (dollars) | (percent) | (dollars) |
| | | | | April, May, June | | | | | |
| Cotton | 0.9880 | 31 | 0.3063 | 45 | 0.4446 | 53 | 0.5236 | 56 | 0.5533 |
| Wheat | 1.3548 | 47 | 0.6368 | 60 | 0.8129 | 69 | 0.9348 | 75 | 1.0161 |
| Grain Sorghum | 0.5886 | 26 | 0.1530 | 37 | 0.2178 | 48 | 0.3835 | 52 | 0.3061 |
| Meadow | 0.0641 | 26 | 0.0167 | 37 | 0.0237 | 48 | 0.0308 | 52 | 0.0333 |
| Pasture | 2.2461 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | | 1.11 | | 1.50 | | 1.77 | | 1.91 |
| | | | July, August, September, and October | | | | | | |
| Cotton | 0.9880 | 41 | 0.4051 | 55 | 0.5434 | 64 | 0.6323 | 65 | 0.6422 |
| Wheat | 1.3548 | 7 | 0.0948 | 9 | 0.1219 | 10 | 0.1355 | 10 | 0.1355 |
| Grain Sorghum | 0.5886 | 40 | 0.2354 | 63 | 0.3708 | 65 | 0.3826 | 68 | 0.4002 |
| Meadow | 0.0641 | 40 | 0.0256 | 63 | 0.0404 | 65 | 0.0417 | 68 | 0.0436 |
| Pasture | 2.2461 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | | 0.76 | | 1.08 | | 1.19 | | 1.22 |
| | | November, December, January, February, and March | | | | | | | |
| Cotton | 0.9880 | 22 | 0.2174 | 30 | 0.2964 | 36 | 0.3557 | 38 | 0.3754 |
| Wheat | 1.3548 | 5 | 0.0677 | 35 | 0.4742 | 50 | 0.6774 | 52 | 0.7045 |
| Grain Sorghum | 0.5886 | 23 | 0.1354 | 26 | 0.1530 | 28 | 0.1648 | 29 | 0.1707 |
| Meadow | 0.0641 | 23 | 0.0147 | 26 | 0.0167 | 28 | 0.0179 | 29 | 0.0186 |
| Pasture | 2.2461 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | | 0.44 | | 0.94 | | 1.22 | | 1.27 |

$150.00 annually. Installation of the recommended program will have a beneficial effect by reducing the acreage scoured annually below the acreage showing annual recovery.

The values of scour damage obtained in this manner were adjusted to 1949 values by the use of the appropriate indexes. No adjustment was made in crop and pasture damage estimates for damage due to scour, because estimates of yields are based on conditions existing at the present time, inclusive of scoured areas.

Other Agricultural Damage: Estimates of other agricultural damage were based upon field questionnaires. Damages to fences, livestock, buildings, trees, farm roads, stored crops and similar agricultural property were tabulated. The totals were converted to a per-acre figure by dividing the acres flooded into the damage from each flood. Then the per-acre damage rate was correlated with the size of flood in proportion to the maximum flood plain inundated. Thus it was found on Mulberry Creek that a flood inundating 60 percent of the flood plain would cause an average "other agricultural" damage at 1948 prices of $1.10 per acre (figure 24). "Other agricultural damages" were adjusted from 1948 levels to those of 1949 by using the indexes of prices paid for items used in production. This conversion factor, 0.9520, was used in all sample areas. The damage of $1.10 per acre under 1947 prices would be $1.047 after adjustment.

Non-agricultural Damage: Road and bridge damage data were obtained on schedules from farmers and from county and state highway departments. Farmers were asked to estimate the amount of damage to roads and bridges with which they were familiar, from specified floods. The areas damaged were definitely located to preclude duplication. These estimates were supplemented by information from highway department offices. The total damage thus estimated from any one flood in a sample tributary was divided by the acreage inundated to arrive at the value per acre of the damage from that flood. Per-acre damages from several floods were plotted against the percentage of the flood plain inundated to arrive at a percentage-inundated-damage relationship. The curve for Mulberry Creek sample tributary at 1948 prices is shown in figure 25.

Urban damages in the Brazos River Watershed are small. Estimates of this type of damage were obtained from city officials and others familiar with local history and from files of local newspapers. Many communities were originally built on the banks of streams to insure a water supply, but have since moved from the flood plain as a result of flooding in early years.

Some industrial installations, such as oil pumping stations, are located on the flood plains of streams. Information on the flood problems of these establishments and flood damages they had sustained was obtained through interviews with field personnel and correspondence with the offices in charge of such installations.

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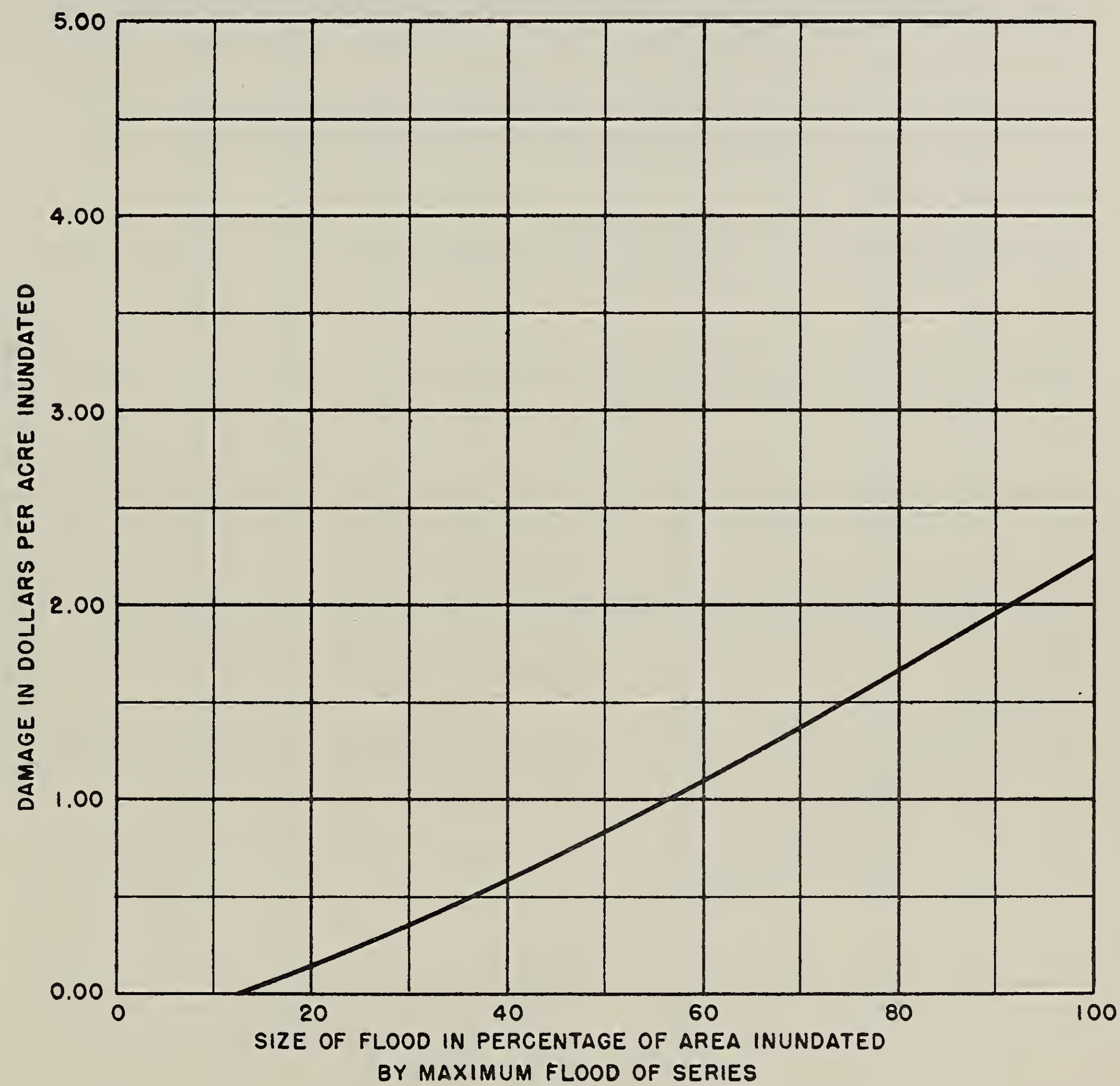


Figure 24

OTHER AGRICULTURAL DAMAGES,
MULBERRY CREEK

BRAZOS RIVER WATERSHED - TEXAS

4-L-7245-11

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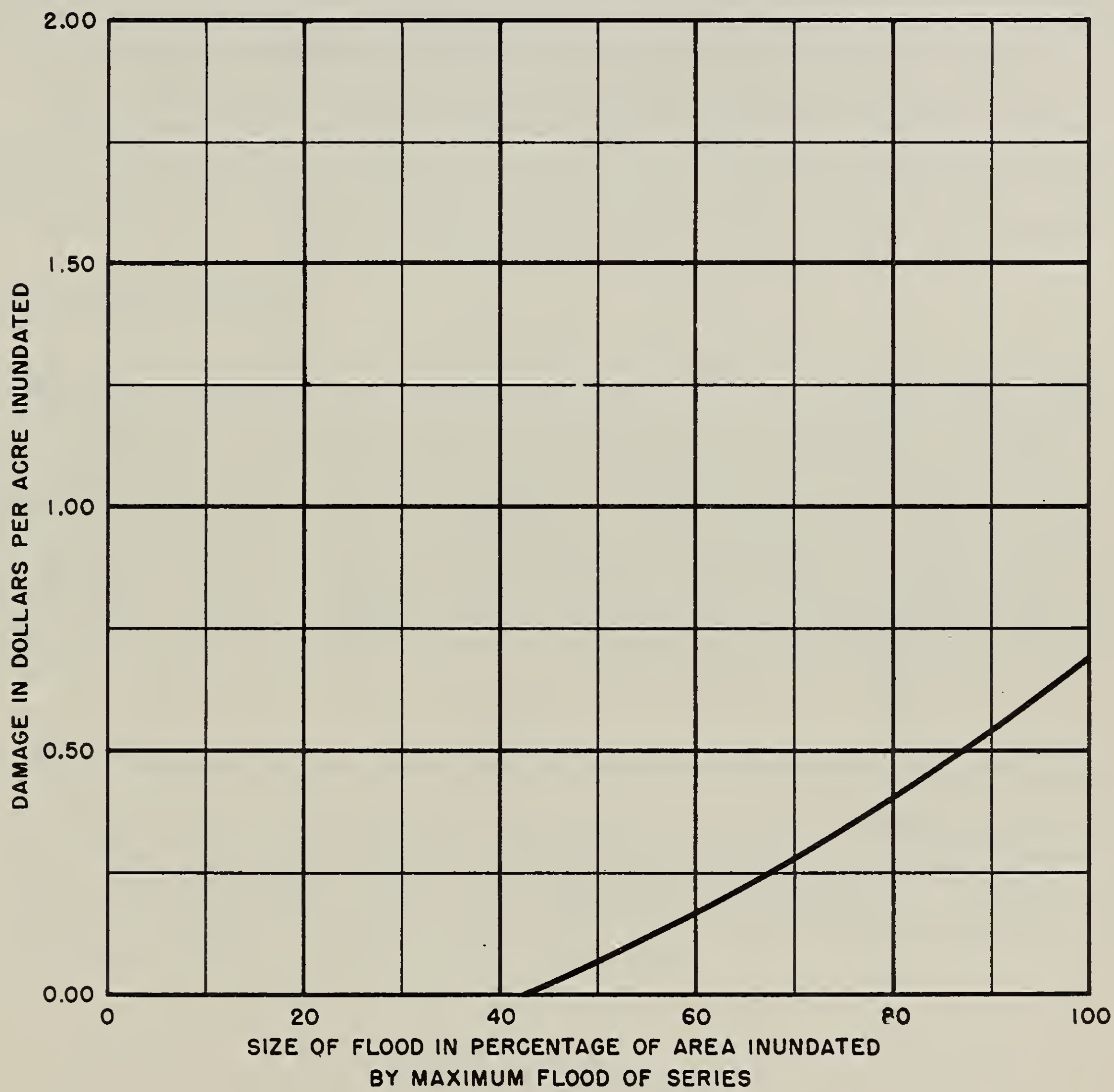


Figure 25

FLOOD DAMAGE TO ROADS, BRIDGES & RAILROADS
MULBERRY CREEK

BRAZOS RIVER WATERSHED - TEXAS

4-L-7245-12

These non-agricultural damages were adjusted from 1948 to 1949 prices by the ENR Index of Construction. This factor, 1.0347, was used in all sample tributaries.

Indirect Damage: Flood damage to crops causes an indirect damage through loss of business in the community. For instance, if part of a cotton crop is destroyed, cotton gins and compresses will lose a part of their normal profits and workers in the gins will suffer loss of wages. Available information 1/ on relationships between the volume of business and the profits and labor earnings was analyzed and curves were constructed showing the relationship of indirect damage of this type to direct damages. Other indirect damages attributable to floods include: losses as a result of delay or rerouting of travel and transportation, relief and rehabilitation of flood victims, and similar items. These losses were estimated from the best available information that could be obtained.

Sedimentation Damages

Valley Sedimentation: The monetary estimates of sediment damage under present conditions were based on the rate of damage during the period of accelerated deposition in the past, an estimated length of time during which this rate of damage may be expected to continue and field information regarding the extra expense of farming when the land has been damaged by sediment to various degrees. These expenses are the extra field operations and fertilization required each year to maintain tilth and fertility. These expenses were calculated for a period of 20 years and brought back to present worth at 4 percent as a capital expenditure.

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1/ Paulson, W. E., "Efficiency as Applied to Cotton Ginning Business", Bull. 654, Texas Agricultural Experiment Station, College Station, Texas; and Billinger, Roy A., "Financial Operations of a Group of Oklahoma Farmers Elevators 1930-32", Bull. 221, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.

The calculations of present damages from overbank deposition of sediment for Mulberry Creek sample area illustrate the method used:

| | |
|---|---|
| Acres damaged annually by sediment . . . . . . . . . . . | 5.3 |
| Present worth of extra expense incurred as a result of sediment damage, per acre . . . . . | $50.00 |
| Annual increment in capital expenditure (5.3 x $50). . . . . . . . . . . . . . . . . . . . | $265.00 |
| Years during which present rate of damage can be expected to continue . . . . . . . . . . . | 30 |
| Present worth of an annuity of $265 per year for 30 years (17.29203 x $265). . . . . . . | $4,582.00 |
| Interest at 4 percent on a capital investment of $4,582 - (annual damage) . . . . . . . . | $183.00 |

There is no duplication of damage from overbank deposition of sediment and floodwater damage by this method, although crop and pasture damage will include a part, but not all, of the damage from loss of fertility.

Reservoir Sedimentation: A study was made of all reservoirs in the Brazos River Watershed on which the storage capacity and the cost of construction were available. A curve was constructed showing the average relationship between storage and the cost of construction, under 1948 prices, per acre-foot of capacity (figure 26). This curve was used to estimate the construction costs of those reservoirs for which definite information could not be obtained.

The cost of each of the reservoirs was adjusted from 1948 to 1949 prices by the ENR Index of Construction Costs. The cost of building a reservoir providing equal useful storage but with no dead storage was determined from the curve of average costs. The remainder of the construction cost was charged as the cost of constructing the dead storage pools. Damage due to sedimentation was calculated on the cost per acre-foot of providing the dead storage only. 1/ In the case of some reservoirs for municipal water supply where no dead storage pool was provided, it was assumed that 20 percent of the total capacity would be equivalent to the dead storage pool.

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1/ On flood control reservoirs recommended or authorized by the Corps of Engineers, the conservation pool was included with the dead storage pool.

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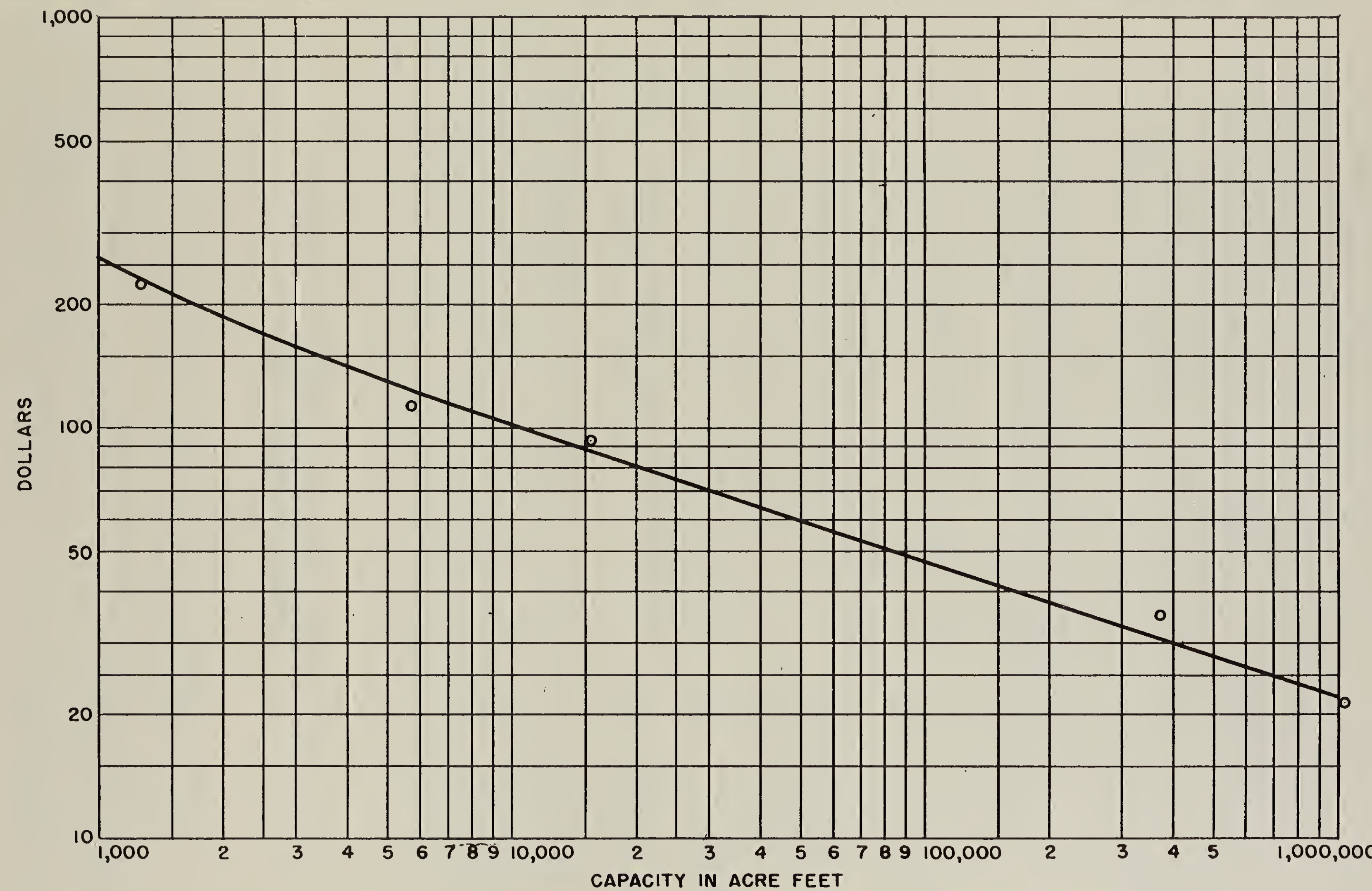


Figure 26

AVERAGE COST OF CONSTRUCTION PER ACRE FOOT OF CAPACITY OF RESERVOIRS OF VARIOUS SIZES

BRAZOS RIVER WATERSHED - TEXAS

Adjusted to 1948 Prices by Engineering News Record price index

4-L-7245-26

The method is illustrated by reference to the Whitney Reservoir.

| | | |
|---|---|---|
| 1. | Original storage capacity | 2,017,500 acre-feet |
| 2. | Total cost to build (1947 estimate) | $32,660,000 |
| 3. | Cost adjusted to 1949 $(\frac{477}{413})$ | $37,722,300 |
| 4. | Cost per acre-foot, 1949 prices | $ 18.698 |
| 5. | Flood control storage capacity | 1,375,300 acre-feet |
| 6. | Ratio of cost per acre-foot of reservoir with 1,375,300 ac.-ft. capacity to one of 2,017,500 ac.-ft. capacity | 1.0968:1 |
| 7. | Cost of flood control storage, per acre-foot | $ 20.508 |
| 8. | Cost of providing 1,375,300 ac.-ft. flood control storage | $28,204,652 |
| 9. | Cost of remaining storage | $ 9,517,648 |
| 10. | Cost per ac.-ft. of other storage | $ 14.820 |
| 11. | Annual damage, present conditions (2,235 x 14.82) | $ 33,123 |

Water Treatment: A considerable number of the cities in the watershed use reservoirs as a source of municipal water supply and treat the water for removal of sediment. The cost of water treatment for sediment removal represents a sediment damage. The estimates of damage from this source, based on present costs, presented in this report are probably low as many of these communities are contemplating construction of additional reservoirs for water supply.

## METHOD OF DETERMINING TOTAL ANNUAL FLOOD AND SEDIMENT DAMAGE

### Application of Flood Occurrences to Per Acre Damage Rates

Per acre values of crop and other agricultural damages, as shown in table 32 and figure 24, were used in determining total agricultural flood damages. The acres flooded by depth-increments and by seasons were estimated from valley cross-sections in sample tributaries and in reaches of the main streams. Curves were then constructed (Appendix III,

figures 20 and 21) to correlate the total acreages flooded with the runoff, and the total crop and grassland damage with the runoff, by seasons for each sample tributary and main stream reach. The area flooded and the total crop and pasture damage by each flood in the period (1933 through 1947) were read directly from the curves for damages both under present conditions and in the future without the recommended program. The average annual damage was calculated by dividing the total damage by the 15 years in the period of record. The figures for Mulberry Creek sample tributary area are given in table 33. Values of the damage in the future with the recommended program installed were obtained from the curves directly, by using the reduced runoff.

It was recognized that a series of floods in a single year would have an effect on the damage to crops by preventing the complete restoration of damageable values between floods. This effect was measured, both under present conditions and after installation of the recommended program, in four sample tributaries by working out the damages after allowance was made for the decrease in damageable value as a result of the preceding flood and for the opportunity for partial restoration of value during the time interval between two consecutive floods. When these results were plotted the relationship shown in figure 27 was obtained. These data, by the method of least squares, give a value of $Y = 100.00 - 0.082266 X$. In this equation X is the percentage of the total flood plain that the average acreage flooded annually represents, and Y is the adjusted damage expressed as a percentage of the damage that would have occurred had each flood been considered as a single event. The coefficient of correlation was 0.980. Adjustments were made in each sample area, as indicated in table 33, for recurrent flooding.

In order to calculate damages from flood plain scour an index of flooding was used. The total acreage flooded during the 15-year period of record under present conditions was taken as 100 percent and the total acreages flooded under future conditions with the recommended program installed were expressed as percentages of the present acreages. The present damage was then multiplied by these percentages to derive the damage under future treated conditions.

For example the average annual loss in production from the approximately 132 acres in Mulberry Creek sample area that are damaged by scour was estimated at $457 (1949 prices).

The total acreage flooded from 1933 through 1947, 95,070 acres (table 33), is taken as 100 percent. Then, 74,730 acres flooded after installation of land treatment measures is 78.6 percent and the 65,307 acres flooded after installation of the floodwater retarding structures represents 68.7 percent. Therefore, the annual damage in Mulberry Creek sample tributary area from flood plain scour is expected to average $359 after installation of land treatment measures and $314 after

Table 33. Crop and Grassland Damage (at 1948 Prices) and Acreage Flooded, by Recorded Floods, 1933-1947, Inclusive
Mulberry Creek Sample Tributary

Brazos River Watershed

| Date of Storm | Under Present Conditions: Area Flooded (acres) | Under Present Conditions: Damage (dollars) | With Land Treatment Measures: Area Flooded (acres) | With Land Treatment Measures: Damage (dollars) | With Recommended Program 1/: Area Flooded (acres) | With Recommended Program 1/: Damage (dollars) |
|---|---|---|---|---|---|---|
| 1. May 23-24,1933 | 6,300 | 8,300 | 5,400 | 6,900 | 4,540 | 5,680 |
| 2. Feb.8, 1945 | 1,280 | 620 | 835 | 383 | 835 | 383 |
| 3. May 14-17,1935 | 5,100 | 6,450 | 4,120 | 5,100 | 3,570 | 4,360 |
| 4. June 12-15,1935 | 2,250 | 2,680 | 1,530 | 1,810 | 1,420 | 1,660 |
| 5. Sept. 2,1935 | 4,200 | 3,630 | 3,310 | 2,860 | 2,850 | 2,360 |
| 6. Sept.15-17,1936 | 6,850 | 6,320 | 6,050 | 5,450 | 5,100 | 4,500 |
| 7. Aug.21, 1937 | 3,980 | 3,420 | 3,120 | 2,680 | 2,650 | 2,190 |
| 8. March 26-28,1938 | 3,720 | 2,180 | 2,720 | 1,480 | 2,280 | 1,210 |
| 9. May 21, 1938 | 6,860 | 9,200 | 6,050 | 7,920 | 5,100 | 6,470 |
| 10. June 8, 1938 | 2,850 | 3,410 | 1,880 | 2,260 | 1,800 | 2,120 |
| 11. July 20-24,1938 | 8,320 | 8,780 | 8,150 | 8,460 | 7,537 | 7,368 |
| 12. May 27-28,1939 | 4,200 | 5,200 | 3,310 | 4,040 | 2,850 | 3,410 |
| 13. June 18-20,1939 | 3,260 | 3,930 | 2,380 | 2,850 | 2,160 | 2,350 |
| 14. Oct. 9, 1939 | 2,500 | 2,130 | 1,640 | 1,420 | 1,550 | 1,270 |
| 15. May 2, 1941 | 4,120 | 5,100 | 3,120 | 3,800 | 2,650 | 3,160 |
| 16. May 21, 1941 | 4,380 | 5,400 | 3,420 | 4,170 | 2,850 | 3,410 |
| 17. June 10, 1941 | 2,380 | 2,850 | 1,640 | 1,960 | 1,530 | 1,820 |
| 18. Oct.15, 1941 | 5,950 | 5,330 | 5,100 | 4,460 | 4,330 | 3,690 |
| 19. Sept. 7, 1942 | 3,980 | 3,420 | 3,120 | 2,680 | 2,650 | 2,190 |
| 20. Oct.16-17,1942 | 3,630 | 3,020 | 2,720 | 2,320 | 2,280 | 1,880 |
| 21. May 22, 1944 | 1,530 | 1,810 | 945 | 1,080 | 945 | 1,080 |
| 22. July 21-22,1944 | 1,280 | 1,090 | 835 | 665 | 835 | 665 |
| 23. Aug. 8, 1945 | 615 | 480 | - | - | - | - |
| 24. Oct. 9, 1945 | 1,280 | 1,090 | 835 | 665 | 835 | 665 |
| 25. May 10, 1947 | 3,420 | 4,170 | 2,500 | 2,980 | 2,160 | 2,550 |
| 26. June 20, 1947 | 835 | 950 | - | - | - | - |
| Total | 95,070 | 100,960 | 74,730 | 78,393 | 65,307 | 66,441 |
| Average Per Year | 6,338 | 6,731 | 4,982 | 5,226 | 4,354 | 4,429 |
| Adjustment Factor for Recurrent Flooding (Figure 27), Percent | | 93.75 | | 95.07 | | 95.70 |
| Adjusted Average Annual Damage | | 6,310 | | 4,968 | | 4,238 |

1/ Land Treatment Measures plus Floodwater Retarding Structures.

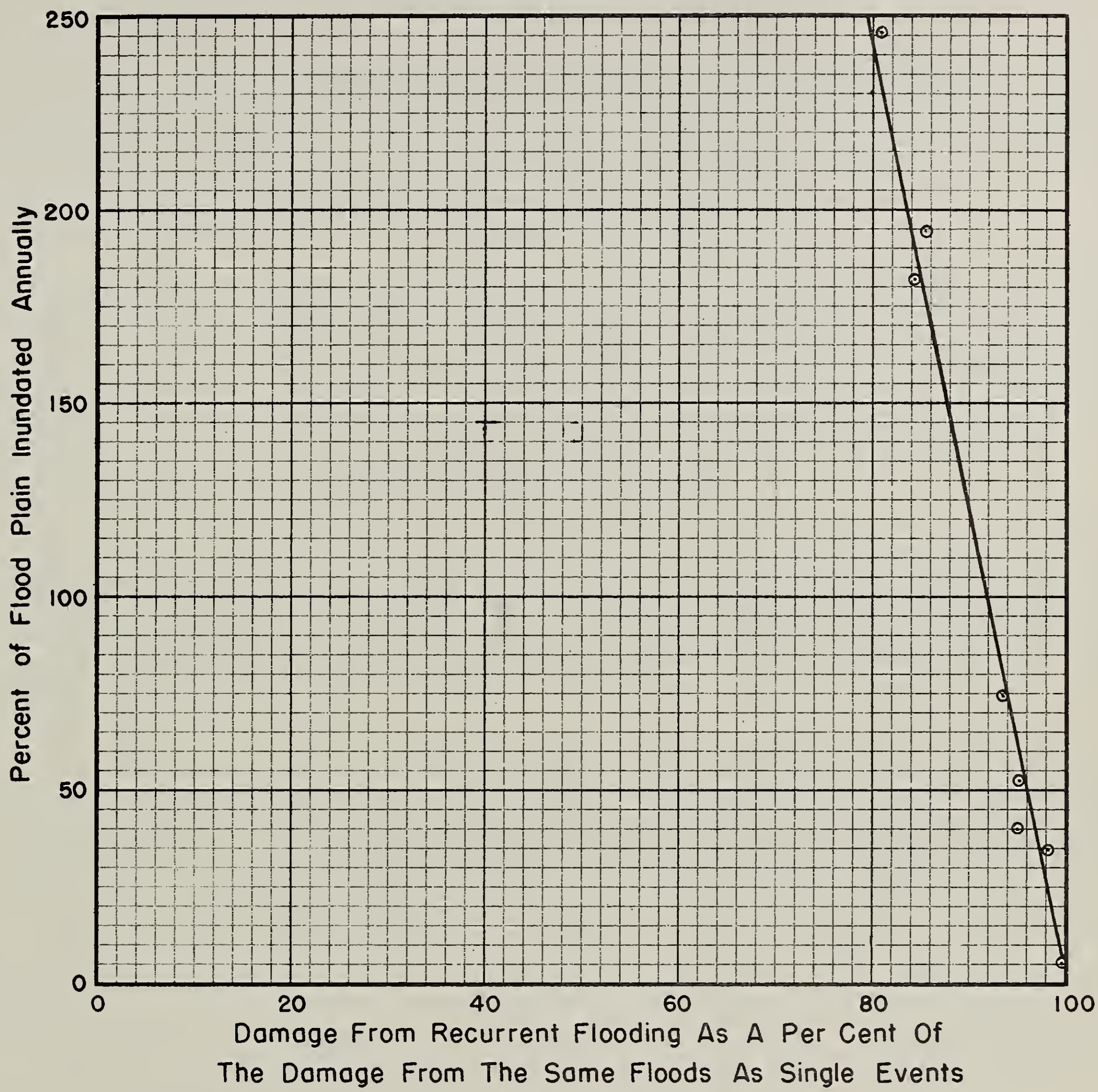


Figure 27

ADJUSTMENT IN FLOOD DAMAGE TO CROPS BECAUSE OF RECURRENCE OF FLOODING DURING CROP YEAR

BRAZOS RIVER WATERSHED - TEXAS

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

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REGION 4 DIRECTOR - LOUIS P. MERRILL

REFERENCE

| CARTOGRAPHIC APPROVAL | | TECHNICAL APPROVAL | |
|---|---|---|---|
| C.B. Eason | | A.H. Bean | |
| COMPILED | TRACED | CHECKED | DATE |
| L.B.A. | F.I.B. | | 8-23-50 |

4-L-7245-29

installation of the floodwater retarding structures. Indexes of flooding on main stream reaches and on sample tributaries are shown in table 34.

This index of flooding was also used in the calculation of reductions in the rate of deposition of valley sediment.

Other agricultural damages were calculated by applying the per acre damage factors (figure 24) to the acreage inundated by each flood in the historical series. The total damage sustained during the period of record was divided by the number of years in the period (15) to determine the average annual damage. This is illustrated in table 35.

Road and bridge damage was calculated by use of percentage of flood plain inundated-damage rate curves (figure 25). The damage rate for each damage-producing flood was read from the curve and applied to the acreage inundated to arrive at the damage from that flood (table 36). The curves for the various sample tributaries differed in the point where damage began, in the slope of the curve, and in maximum damage rate, but they were similar in general shape and characteristics.

Damage to urban communities and industrial installations was calculated directly in the areas concerned. Damages from sedimentation of reservoirs were apportioned back to the subwatersheds in the reservoir drainage area on the basis of sediment output of the subwatershed and its distance above the reservoir.

When the average annual damages under present conditions and with only the land treatment measures installed, by types of damage other than urban, industrial, and reservoir and valley sedimentation, were calculated for a sample tributary (table 37) they were expanded to the subwatershed in the ratio of the drainage area of the sample tributary to the entire drainage area in the subwatershed represented by that sample. Reductions in damages after installation of floodwater retarding structures or channel improvement were not expanded on the areal base, but they were dependent on the amounts of these independent measures installed. No expansion was made for reaches of the main stream in the subwatershed. Table 38 illustrates this procedure for the Clear Fork subwatershed.

A summary of all floodwater and sediment damages is shown in table 39 and their present location in figure 23.

Table 34. Index of Area Flooding, All Floods under Present Conditions and with the Recommended Program

Brazos River Watershed

| Main Stream Reach or Sample Tributary | Flood Index: Under Present Conditions (percent) | With Land Treatment Measures (percent) | With Land Treatment and Floodwater Retarding Structures (percent) | With Land Treatment, Floodwater Retarding Structures, and Channel Improvement (percent) |
|---|---|---|---|---|
| Aquilla Creek | 100 | 76.0 | 58.8 | 2/ |
| Brazos Main Stem above Clear Fork | 100 | 82.4 | 1/ | 2/ |
| California Creek | 100 | 80.8 | 1/ | 2/ |
| Castleman Creek, Lower | 100 | 82.4 | 67.9 | 57.6 |
| Clear Fork (Reaches 1-4) | 100 | 32.8 | 11.7 | 2/ |
| Clear Fork (Reaches 7-11) | 100 | 68.6 | 61.8 | 2/ |
| Duck Creek | 100 | 82.3 | 62.8 | 2/ |
| Hubbard Creek | 100 | 78.6 | 33.8 | 2/ |
| Keechi Creek | 100 | 80.8 | 54.8 | 2/ |
| Lake Creek | 100 | 70.7 | 1/ | 2/ |
| Little Brazos River | 100 | 70.2 | 51.5 | 2/ |
| Mulberry Creek | 100 | 78.6 | 68.7 | 2/ |
| Nails Creek | 100 | 79.9 | 68.6 | 2/ |
| Navasota Main Stream | 100 | 83.1 | 74.0 | 37.9 |
| Navasota Sample | 100 | 81.4 | 71.2 | 54.1 |
| New Years Creek | 100 | 93.3 | 82.7 | 76.6 |
| Palo Pinto Main Stream | 100 | 84.0 | 17.0 | 2/ |
| Palo Pinto (South Fork) | 100 | 81.3 | 15.9 | 2/ |
| Paluxy Creek | 100 | 66.8 | 19.6 | 2/ |
| Tehuacana Creek | 100 | 84.5 | 64.9 | 49.9 |

1/ Floodwater retarding structures not recommended at this time.

2/ Channel improvement not recommended at this time.

Table 35. Other Agricultural Damages (at 1948 Prices) by Recorded Floods, 1933-1947, Inclusive
Mulberry Creek Sample Tributary

Brazos River Watershed

| Series Number of Flood 1/ | Under Present Conditions | | | With Land Treatment Measures Installed | | | With Recommended Program Installed 2/ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Area Flooded | Damage Per Acre | Total Damage | Area Flooded | Damage Per Acre | Total Damage | Area Flooded | Damage Per Acre | Total Damage |
| | (acres) | (dollars) | (dollars) | (acres) | (dollars) | (dollars) | (acres) | (dollars) | (dollars) |
| 1 | 6,300 | 1.56 | 9,828 | 5,400 | 1.24 | 6,696 | 4,540 | 0.97 | 4,404 |
| 2 | 1,280 | 0.05 | 64 | 835 | 0 | - | 835 | 0 | - |
| 3 | 5,100 | 1.13 | 5,763 | 4,120 | 0.83 | 3,420 | 3,570 | 0.65 | 2,320 |
| 4 | 2,250 | 0.28 | 630 | 1,530 | 0.10 | 153 | 1,420 | 0.08 | 114 |
| 5 | 4,200 | 0.83 | 3,486 | 3,310 | 0.56 | 1,854 | 2,850 | 0.43 | 1,226 |
| 6 | 6,850 | 1.73 | 11,850 | 6,050 | 1.47 | 8,894 | 5,100 | 1.13 | 5,763 |
| 7 | 3,980 | 0.77 | 3,065 | 3,120 | 0.50 | 1,560 | 2,650 | 0.38 | 1,007 |
| 8 | 3,720 | 0.69 | 2,567 | 2,720 | 0.40 | 1,088 | 2,280 | 0.28 | 638 |
| 9 | 6,860 | 1.73 | 11,868 | 6,050 | 1.47 | 8,894 | 5,100 | 1.13 | 5,763 |
| 10 | 2,850 | 0.43 | 1,226 | 1,880 | 0.20 | 376 | 1,800 | 0.18 | 324 |
| 11 | 8,320 | 2.25 | 18,720 | 8,150 | 2.20 | 17,930 | 7,537 | 1.99 | 14,999 |
| 12 | 4,200 | 0.83 | 3,486 | 3,310 | 0.56 | 1,854 | 2,850 | 0.43 | 1,226 |
| 13 | 3,260 | 0.54 | 1,760 | 2,380 | 0.32 | 762 | 2,160 | 0.26 | 562 |
| 14 | 2,500 | 0.34 | 850 | 1,640 | 0.14 | 230 | 1,550 | 0.12 | 186 |
| 15 | 4,120 | 0.83 | 3,420 | 3,120 | 0.50 | 1,560 | 2,650 | 0.38 | 1,007 |
| 16 | 4,380 | 0.90 | 3,852 | 3,420 | 0.59 | 2,018 | 2,850 | 0.43 | 1,226 |
| 17 | 2,380 | 0.32 | 762 | 1,640 | 0.14 | 231 | 1,530 | 0.10 | 153 |
| 18 | 5,950 | 1.44 | 8,568 | 5,100 | 1.13 | 5,763 | 4,330 | 0.88 | 3,810 |
| 19 | 3,980 | 0.77 | 3,065 | 3,120 | 0.50 | 1,560 | 2,650 | 0.38 | 1,007 |
| 20 | 3,630 | 0.67 | 2,432 | 2,720 | 0.40 | 1,088 | 2,280 | 0.28 | 638 |
| 21 | 1,530 | 0.10 | 153 | 945 | 0 | - | 945 | 0 | - |
| 22 | 1,280 | 0.05 | 64 | 835 | 0 | - | 835 | 0 | - |
| 23 | 615 | 0 | - | - | - | - | - | - | - |
| 24 | 1,280 | 0.05 | 64 | 835 | 0 | - | 835 | 0 | - |
| 25 | 3,420 | 0.59 | 2,018 | 2,500 | 0.34 | 850 | 2,160 | 0.26 | 562 |
| 26 | 835 | 0 | - | - | - | - | - | - | - |
| Total | 95,070 | | 99,561 | 74,730 | | 66,781 | 65,307 | | 46,935 |
| Ave. Annual Damage | | | 6,637 | | | 4,452 | | | 3,129 |

1/ For date of flood, see table 33.
2/ Land Treatment Measures plus Floodwater Retarding Structures.

Table 36. Damage to Roads, Bridges, and Railroads (at 1948 Prices) by Recorded Floods, 1933-1947, Inclusive
Mulberry Creek Sample Tributary

Brazos River Watershed

| Series | Under Present Conditions | | | With Land Treatment Measures Installed | | | With Recommended Program Installed 2/ | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of Flood 1/ | Area Flooded | Damage Per Acre | Total Damage | Area Flooded | Damage Per Acre | Total Damage | Area Flooded | Damage Per Acre | Total Damage |
| | (acres) | (dollars) | (dollars) | (acres) | (dollars) | (dollars) | (acres) | (dollars) | (dollars) |
| 1 | 6,300 | 0.35 | 2,205 | 5,400 | 0.22 | 1,188 | 4,540 | 0.12 | 545 |
| 3 | 5,100 | 0.18 | 918 | 4,120 | 0.06 | 247 | 3,570 | 0.01 | 36 |
| 5 | 4,200 | 0.06 | 252 | 3,310 | 0 | - | 2,850 | 0 | - |
| 6 | 6,850 | 0.42 | 2,877 | 6,050 | 0.31 | 1,876 | 5,100 | 0.18 | 918 |
| 7 | 3,980 | 0.05 | 199 | 3,120 | 0 | - | 2,650 | 0 | - |
| 8 | 3,720 | 0.02 | 74 | 2,720 | 0 | - | 2,280 | 0 | - |
| 9 | 6,860 | 0.42 | 2,881 | 6,050 | 0.31 | 1,876 | 5,100 | 0.18 | 918 |
| 11 | 8,320 | 0.69 | 5,741 | 8,150 | 0.66 | 5,379 | 7,537 | 0.55 | 4,145 |
| 12 | 4,200 | 0.06 | 252 | 3,310 | 0 | - | 2,850 | 0 | - |
| 15 | 4,120 | 0.06 | 247 | 3,120 | 0 | - | 2,650 | 0 | - |
| 16 | 4,380 | 0.10 | 438 | 3,420 | 0 | - | 2,850 | 0 | - |
| 18 | 5,950 | 0.30 | 1,785 | 5,100 | 0.18 | 918 | 4,330 | 0.09 | 390 |
| 19 | 3,980 | 0.05 | 199 | 3,120 | 0 | - | 2,650 | 0 | - |
| 20 | 3,630 | 0.01 | 36 | 2,720 | 0 | - | 2,280 | 0 | - |
| Total | | | 18,104 | | | 11,484 | | | 6,952 |
| Ave. Annual Damage | | | 1,207 | | | 766 | | | 463 |

1/ For date of flood see table 33. Floods causing no road, bridge or railroad damage omitted from tabulation.

2/ Land Treatment Measures plus Floodwater Retarding Structures.

Table 37. Summary of Annual Floodwater Damages, 1949 Prices, Under Present Conditions After Installation of Land Treatment Measures and After Installation of the Recommended Program

Mulberry Creek Sample Tributary

Brazos River Watershed

| | Conversion Factor, 1948 to 1949 Prices | Average Annual Damage | | |
|---|---|---|---|---|
| | | Under Present Condition | After Land Treatment Measures 2/ | After Recommended Program 3/ |
| | | (dollars) | (dollars) | (dollars) |
| Crops and Grassland | 0.8438 1/ | 5,324 | 4,192 | 3,576 |
| Flood Plain Scour | 0.9957 | 457 | 360 | 314 |
| Other Agricultural | 0.9520 | 6,318 | 4,238 | 2,979 |
| Roads, Bridges, Railroads | 1.0347 | 1,249 | 793 | 479 |
| Indirect | 0.9683 | 670 | 537 | 421 |

1/ Value of grassland not included, no flood damage to grass in this area.

2/ With the going program and the land treatment measures of the recommended program installed.

3/ With both the going program and the recommended program (including independent measures) installed.

Table 38. Summary of Floodwater and Sediment Damage, 1949 Prices, Under Present Conditions, With Land Treatment Measures, and with Land Treatment Measures Plus Floodwater Retarding Structures Installed, Clear Fork Subwatershed

Brazos River Watershed

| Portion of Subwatershed<br>Type of Damage | Area Expansion Factor | Average Annual Damage<br>Under Present Conditions<br>(dollars) | With Land Treatment Measures Installed 1/<br>(dollars) | Floodwater Retarding Structures Added 2/<br>(dollars) |
|---|---|---|---|---|
| Main Stream (Reaches 7-11) | 1.00 | | | |
| Crop and Grassland | | 33,518 | 21,222 | 18,945 |
| Flood Plain Scour | | 145 | 100 | 90 |
| Other Agricultural | | 4,967 | 2,551 | 1,834 |
| Roads, Bridges, R.R. | | 574 | 162 | 50 |
| Indirect | | 4,454 | 2,835 | 2,228 |
| Main Stream (Reaches 1-4) | 1.00 | | | |
| Crop and Grassland | | 12,699 | 4,292 | 1,523 |
| Flood Plain Scour | | 179 | 58 | 21 |
| Other Agricultural | | 5,769 | 1,378 | 92 |
| Roads, Bridges, R.R. | | 1,076 | 107 | 0 |
| Indirect | | 1,520 | 438 | 58 |
| Mulberry Creek | 9.22 | | | |
| Crop and Grassland | | 49,087 | 38,650 | 33,728 |
| Flood Plain Scour | | 4,214 | 3,319 | 2,997 |
| Other Agricultural | | 58,252 | 39,074 | 29,011 |
| Roads, Bridges, R.R. | | 11,516 | 7,311 | 5,113 |
| Indirect | | 6,181 | 4,952 | 4,143 |
| Subwatershed | | | | |
| Crop and Grassland | | 95,304 | 64,164 | 54,196 |
| Flood Plain Scour | | 4,538 | 3,477 | 3,108 |
| Other Agricultural | | 68,988 | 43,003 | 30,937 |
| Roads, Bridges, R.R. | | 13,166 | 7,580 | 5,163 |
| Other Non-Agricultural | | 1,607 | 854 | 575 |
| Valley Sediment Deposition | | 1,999 | 1,686 | 1,525 |
| Reservoir Sediment Deposition | | 41,941 | 28,766 | 15,590 |
| Water Treatment | | 3,883 | 2,640 | 1,436 |
| Indirect | | 12,155 | 8,225 | 6,429 |
| Grand Total | | 243,581 | 160,395 | 118,959 |

1/ With the going program and the land treatment measures of the recommended program installed.

2/ With both the going program and the land treatment measures of the recommended program and floodwater retarding structures installed.

Table 39. Average Annual Flood Damages, 1949 Prices, by Subwatersheds

Brazos River Watershed

| Subwatershed | Average Annual Floodwater and Sedimentation Damage | | | |
|---|---|---|---|---|
| | Under Present Conditions | With Land Treatment Measures Installed 1/ | With Floodwater Retarding Structures Added | With Channel Improvement Added |
| | (dollars) | (dollars) | (dollars) | (dollars) |
| Salt Fork | 64,734 | 53,775 | 41,321 2/ | 41,321 |
| Brazos above Possum Kingdom | 171,357 | 130,259 | 130,259 | 130,259 |
| California Creek | 135,860 | 108,691 | 108,691 | 108,691 |
| Elm Creek | 48,474 | 33,163 | 33,163 | 33,163 |
| Hubbard Creek | 52,831 | 40,516 | 19,703 2/ | 19,703 |
| Clear Fork | 243,581 | 160,395 | 118,959 2/ | 118,959 |
| Possum Kingdom | 28,878 | 22,796 | 14,878 2/ | 14,878 |
| Possum Kingdom to Whitney | 310,749 | 252,010 | 221,264 3/ | 221,264 |
| Palo Pinto | 39,739 | 31,553 | 11,814 2/ | 11,814 |
| Paluxy Creek | 212,124 | 173,734 | 127,205 3/ | 127,205 |
| Nolands River | 34,357 | 26,209 | 26,209 | 26,209 |
| Aquilla Creek | 394,331 | 305,624 | 246,722 | 246,722 |
| Whitney to Waco | 87,847 | 72,405 | 67,923 | 67,923 |
| Waco to Little River | 1,769,123 | 1,457,645 | 1,145,595 | 1,041,179 |
| Little Brazos | 1,890,464 | 1,381,996 | 999,984 | 999,984 |
| Navasota above Dam | 510,208 | 411,816 | 352,221 | 294,442 |
| Yegua above Dam | 134,506 | 104,491 | 84,108 | 84,108 |
| Mill Creek | 258,335 | 237,058 | 202,273 2/ | 197,534 2/ |
| Little River to Irrigation | 273,683 | 251,140 | 213,397 2/ | 206,319 2/ |
| Brazos exclusive of Little and Bosque Rivers | 6,661,181 | 5,255,276 | 4,165,689 3/ | 3,991,677 3/ |
| Little River | 7,396,703 | 5,985,612 | 3,615,598 | 3,560,675 |
| Bosque River | 492,192 | 373,632 | 239,316 | 239,316 |
| Total - Brazos River Watershed | 14,550,076 | 11,614,520 | 8,020,603 3/ | 7,791,668 3/ |

1/ Includes the going program and the land treatment measures of the recommended program.

2/ Independent measures not recommended at this time.

3/ Only a portion of these independent measures recommended at this time.

## APPENDIX V

### RECOMMENDED PROGRAM

Field Examinations of conditions were made in all sample tributary watersheds (figure 12). All measures and practices applicable to the various conservation problem areas were considered. A determination was made as to which measures were of primary importance to the objectives of runoff and waterflow retardation and soil erosion control. Soil Conservation Service work unit personnel, regional technicians and soil conservation district supervisors were consulted concerning the need for, and the feasibility of, measures in determining whether they should be included in the recommended program.

To assist in analysis of the effects and costs of measures or combinations of measures, the following groupings were made: 1/

1. Those parts of the going agricultural programs in the watershed which were deemed of primary importance to the objectives of the Flood Control Act. It was assumed that the application of such measures would continue at a rate at least equal to the present rate, as measured by records of agricultural agencies for the period 1946 through 1949. Since the measures in this group are currently being installed, the portions which can be expected to be installed during the evaluation period are not included in the recommended program nor are they discussed in detail; see 2 (a) below.

2. The program recommended in this report is as follows:

   (a) The acceleration, intensification, or adaptation of such portions of the going programs to the extent necessary to achieve flood control objectives. This portion of the recommended program is called land treatment measures.

   (b) Additional measures not now regularly installed but considered necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. This portion of the recommended program is called independent measures.

The present speed of application of measures under the going programs and the possibilities of acceleration was considered in estimating the time which would be necessary to apply the recommended

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1/ Pages 1 and 2 of Secretary's memorandum dated Sept. 29, 1949: Subject "Policies and Procedures to Guide the Preparation of Flood Control Survey Reports", as amended and supplemented, Jan. 6, 1950.

program. It was decided that an installation period of approximately 15 years would be necessary for completion of the recommended program on substantially all farms and ranches in the watershed.

Investigation of damages and possible benefits showed that some areas in the watershed would not justify, at this time, the acceleration of land treatment measures. In these areas the going programs of land treatment measures are assumed to continue at their present rates and acceleration is not recommended at this time. The areas are shown on figure 28 and comprise the High Plains, a large portion of the Rolling Red Plains and the Cost Prairie conservation problem areas.

The following sections describe the measures which are included in the recommended program. Quantities of measures, their cost of installation and the distribution of these costs are presented in table 40. The average annual costs of the recommended program are shown in table 41.

Two Interim Survey Reports 1/ on watersheds tributary to the Brazos River in Texas have been completed. These are the Little River Watershed and the Bosque River Watershed. Each presents a program of runoff and the waterflow retardation and soil erosion prevention for its drainage area. In this report these two river watersheds are considered as subwatersheds of the Brazos River Watershed and the measures, costs and benefits are included as an integral part of the program herein recommended for the Brazos River Watershed.

Maintenance of practices and measures on non-Federal land is considered the primary responsibility of local or private interests. The estimated costs thereof are presented in the report as non-Federal but it is recognized that the Department of Agriculture has responsibilities to see that the maintenance is carried out to the extent that the going programs of the Department cannot adequately meet these requirements of maintenance. The Secretary may request funds under appropriate authorities for carrying out maintenance of these measures and practices.

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1/ Brazos River and Tributaries, Interim Survey Report, Department of Agriculture, Little River Watershed, Texas, July 1950.

Brazos River and Tributaries, Interim Survey Report, Department of Agriculture, Bosque River Watershed, Texas, July 1950.

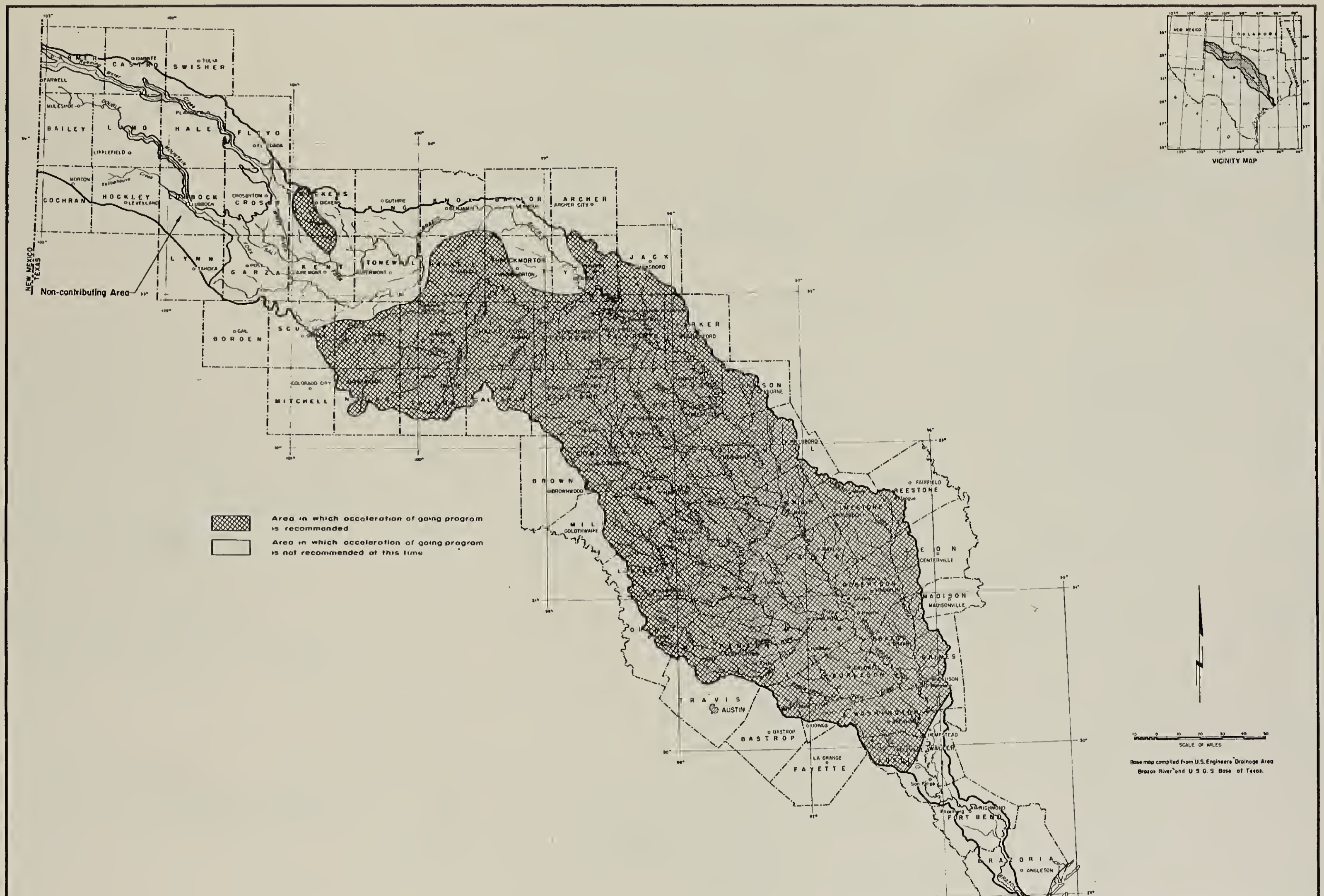


Figure 28
AREA IN WHICH ACCELERATION OF GOING PROGRAM IS RECOMMENDED
BRAZOS RIVER WATERSHED - TEXAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H H BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P MERRILL

| COMPILED | TRACED | CHECKED | DATE | |
|---|---|---|---|---|
| LAK | | GLB | 9/13/50 | 4-R-7245-31 |

Table 40 - Quantities of Measures and Distribution of Installation Costs
of the Recommended Program ( 1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Total Brazos River Watershed** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 115,651 | 8,100,465 | - | 7,294,766 | 15,395,231 |
| Field Diversions | Acre | 2,985 | 587,224 | - | 312,246 | 899,470 |
| Cover Crops | Acre | 193,100 | 531,025 | - | 193,100 | 724,125 |
| Farm and Group Waterways | Mile | 5,243 | 180,377 | - | 621,273 | 801,650 |
| Gully Stabilization | Mile | 2,378 | 1,750,288 | - | 1,106,454 | 2,856,742 |
| Establishment of New Grassland | Acre | 233,696 | 1,293,920 | - | 5,471,426 | 6,765,346 |
| Improvement and Management of Existing Grassland | Acre | 3,782,897 | 6,544,990 | - | 12,431,381 | 18,976,371 |
| Fire Protection | Acre | 500,000 | 112,500 | 37,500 | - | 150,000 |
| Technical Services | - | - | 14,194,605 | - | - | 14,194,605 |
| Educational Assistance | - | - | 656,250 | 656,250 | - | 1,312,500 |
| Administrative Cost of Direct Aids | - | - | 975,720 | - | - | 975,720 |
| Total | - | - | 34,927,364 | 693,750 | 27,430,646 | 63,051,760 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 555 | 31,968,480 | 8,884,161 | 1,813,779 | 42,666,420 |
| Floodway and Channel Improvements | Mile | 80.95 | 1,661,837 | - | 1,159,088 | 2,820,925 |
| Total | - | - | 33,630,317 | 8,884,161 | 2,972,867 | 45,487,345 |
| Grand Total | - | - | 68,557,681 | 9,577,911 | 30,403,513 | 108,539,105 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices) Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | Federal | Non-Federal Public | Non-Federal Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Salt Fork** | | | | | | |
| Land Treatment Measures | | | | | | |
| Farm and Group Waterways | Mile | 14 | 526 | - | 1,812 | 2,338 |
| Establishment of New Grassland | Acre | 2,558 | 7,674 | - | 45,456 | 53,130 |
| Improvement and Management of Existing Grassland | Acre | 101,795 | 19,815 | - | 11,852 | 31,667 |
| Technical Services | - | - | 2,460 | - | - | 2,460 |
| Educational Assistance | - | - | 1,298 | 1,297 | - | 2,595 |
| Administrative Cost of Direct Aids | - | - | 2,130 | - | - | 2,130 |
| Total | - | - | 33,903 | 1,297 | 59,120 | 94,320 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 33,903 | 1,297 | 59,120 | 94,320 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices) Brazos River, Texas.

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | Federal | Non-Federal Public | Non-Federal Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Brazos Above Possum Kingdom** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 3,542 | 247,940 | - | 166,474 | 414,414 |
| Field Diversions | Acre | 74 | 15,984 | - | 8,436 | 24,420 |
| Farm and Group Waterways | Mile | 40 | 1,504 | - | 5,176 | 6,680 |
| Establishment of New Grassland | Acre | 4,733 | 14,199 | - | 84,105 | 98,304 |
| Improvement and Management of Existing Grassland | Acre | 453,651 | 379,396 | - | 509,613 | 889,009 |
| Technical Services | - | - | 148,155 | - | - | 148,155 |
| Educational Assistance | - | - | 20,767 | 20,768 | - | 41,535 |
| Administrative Cost of Direct Aids | - | - | 34,140 | - | - | 34,140 |
| Total | - | - | 862,085 | 20,768 | 773,804 | 1,656,657 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 862,085 | 20,768 | 773,804 | 1,656,657 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices) Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | Federal | Non-Federal Public | Non-Federal Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **California Creek** | | | | | | |
| Land Treatment Measures | | | | | | |
| Farm and Group Waterways | Mile | 80 | 3,006 | - | 10,354 | 13,360 |
| Establishment of New Grassland | Acre | 13,837 | 41,895 | - | 245,254 | 287,149 |
| Improvement and Management of Existing Grassland | Acre | 148,641 | 77,831 | - | 124,047 | 201,878 |
| Technical Services | - | - | 10,770 | - | - | 10,770 |
| Educational Assistance | - | - | 7,440 | 7,440 | - | 14,880 |
| Administrative Cost of Direct Aids | - | - | 12,225 | - | - | 12,225 |
| Total | - | - | 153,167 | 7,440 | 379,655 | 540,262 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 153,167 | 7,440 | 379,655 | 540,262 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices) Brazos River, Texas.

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| Elm Creek | | | | | | |
| Land Treatment Measures | | | | | | |
| Farm and Group Waterways | Mile | 28 | 1,052 | - | 3,624 | 4,676 |
| Establishment of New Grassland | Acre | 5,129 | 15,879 | - | 90,335 | 106,214 |
| Improvement and Management of Existing Grassland | Acre | 77,004 | 75,880 | - | 143,677 | 219,557 |
| Technical Services | - | - | 8,505 | - | - | 8,505 |
| Educational Assistance | - | - | 4,770 | 4,770 | - | 9,540 |
| Administrative Cost of Direct Aids | - | - | 7,845 | - | - | 7,845 |
| Total | - | - | 113,931 | 4,770 | 237,636 | 356,337 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 113,931 | 4,770 | 237,636 | 356,337 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | Federal | Non-Federal Public | Non-Federal Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| Hubbard Creek | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 5,207 | 364,490 | - | 244,729 | 609,219 |
| Field Diversions | Acre | 110 | 23,760 | - | 12,540 | 36,300 |
| Farm and Group Waterways | Mile | 194 | 7,291 | - | 25,107 | 32,398 |
| Establishment of New Grassland | Acre | 205 | 1,230 | - | 2,634 | 3,864 |
| Improvement and Management of Existing Grassland | Acre | 426,438 | 583,722 | - | 884,435 | 1,468,157 |
| Technical Services | - | - | 797,385 | - | - | 797,385 |
| Educational Assistance | - | - | 30,968 | 30,967 | - | 61,935 |
| Administrative Cost of Direct Aids | - | - | 50,895 | - | - | 50,895 |
| Total | - | - | 1,859,741 | 30,967 | 1,169,445 | 3,060,153 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 1,859,741 | 30,967 | 1,169,445 | 3,060,153 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | Federal | Non-Federal | | Total |
| | | | | Public | Private | |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| | | Clear Fork | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 1,840 | 128,800 | - | 86,480 | 215,280 |
| Field Diversions | Acre | 39 | 8,424 | - | 4,446 | 12,870 |
| Farm and Group Waterways | Mile | 152 | 5,712 | - | 19,672 | 25,384 |
| Establishment of New Grassland | Acre | 25,069 | 78,084 | - | 440,758 | 518,842 |
| Improvement and Management of Existing Grassland | Acre | 542,076 | 609,876 | - | 1,082,659 | 1,692,535 |
| Technical Services | - | - | 122,640 | - | - | 122,640 |
| Educational Assistance | - | - | 35,490 | 35,490 | - | 70,980 |
| Administrative Cost of Direct Aids | - | - | 58,335 | - | - | 58,335 |
| Total | - | - | 1,047,361 | 35,490 | 1,634,015 | 2,716,866 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 1,047,361 | 35,490 | 1,634,015 | 2,716,866 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs
of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| | | Possum Kingdom | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 4,069 | 288,058 | - | 196,736 | 484,794 |
| Field Diversions | Acre | 151 | 32,616 | - | 16,059 | 48,675 |
| Farm and Group Waterways | Mile | 35 | 1,607 | - | 5,535 | 7,142 |
| Gully Stabilization | Mile | 15 | 20,130 | - | 7,425 | 27,555 |
| Establishment of New Grassland | Acre | 436 | 3,270 | - | 9,405 | 12,675 |
| Improvement and Management of Existing Grassland | Acre | 276,274 | 354,092 | - | 525,500 | 879,592 |
| Technical Services | - | - | 520,020 | - | - | 520,020 |
| Educational Assistance | - | - | 21,210 | 21,210 | - | 42,420 |
| Administrative Cost of Direct Aids | - | - | 34,860 | - | - | 34,860 |
| Total | - | - | 1,275,863 | 21,210 | 760,660 | 2,057,733 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 1,275,863 | 21,210 | 760,660 | 2,057,733 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs
of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| Possum Kingdom to Whitney | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 7,495 | 546,046 | - | 419,852 | 965,898 |
| Field Diversions | Acre | 386 | 83,376 | - | 40,299 | 123,675 |
| Farm and Group Waterways | Mile | 154 | 7,159 | - | 24,656 | 31,815 |
| Gully Stabilization | Mile | 425 | 567,300 | - | 209,250 | 776,550 |
| Establishment of New Grassland | Acre | 12,116 | 90,870 | - | 261,342 | 352,212 |
| Improvement and Management of Existing Grassland | Acre | 596,672 | 844,319 | - | 1,568,442 | 2,412,761 |
| Technical Services | - | - | 1,864,665 | - | - | 1,864,665 |
| Educational Assistance | - | - | 68,295 | 68,295 | - | 136,590 |
| Administrative Cost of Direct Aids | - | - | 112,230 | - | - | 112,230 |
| Total | - | - | 4,184,260 | 68,295 | 2,523,841 | 6,776,396 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 9 | 1,074,576 | 109,386 | 58,026 | 1,241,988 |
| Total | - | - | 1,074,576 | 109,386 | 58,026 | 1,241,988 |
| Grand Total | - | - | 5,258,836 | 177,681 | 2,581,867 | 8,018,384 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| | Pale Pinto Creek | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 2,495 | 177,574 | - | 127,174 | 304,748 |
| Field Diversions | Acre | 86 | 18,576 | - | 9,279 | 27,855 |
| Farm and Group Waterways | Mile | 25 | 1,104 | - | 3,806 | 4,910 |
| Gully Stabilization | Mile | 65 | 86,620 | - | 31,950 | 118,570 |
| Establishment of New Grassland | Acre | 1,839 | 13,793 | - | 39,667 | 53,460 |
| Improvement and Management of Existing Grassland | Acre | 180,914 | 250,748 | - | 405,060 | 655,808 |
| Technical Services | - | - | 446,895 | - | - | 446,895 |
| Educational Assistance | - | - | 16,987 | 16,988 | - | 33,975 |
| Administrative Cost of Direct Aids | - | - | 27,930 | - | - | 27,930 |
| Total | - | - | 1,040,227 | 16,988 | 616,936 | 1,674,151 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 1,040,227 | 16,988 | 616,936 | 1,674,151 |

Table 40 (continued)- Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices) Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| Paluxy Creek | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 1,142 | 84,508 | - | 66,839 | 151,347 |
| Field Diversions | Acre | 84 | 18,144 | - | 8,631 | 26,775 |
| Farm and Group Waterways | Mile | 32 | 1,523 | - | 5,243 | 6,766 |
| Gully Stabilization | Mile | 60 | 81,740 | - | 30,150 | 111,890 |
| Establishment of New Grassland | Acre | 2,185 | 16,388 | - | 47,130 | 63,518 |
| Improvement and Management of Existing Grassland | Acre | 87,736 | 121,408 | - | 241,947 | 363,355 |
| Technical Services | - | - | 286,260 | - | - | 286,260 |
| Educational Assistance | - | - | 10,613 | 10,612 | - | 21,225 |
| Administrative Cost of Direct Aids | - | - | 17,445 | - | - | 17,445 |
| Total | - | - | 638,029 | 10,612 | 399,940 | 1,048,581 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 15 | 1,244,028 | 97,897 | 68,353 | 1,410,278 |
| Total | - | - | 1,244,028 | 97,897 | 68,353 | 1,410,278 |
| Grand Total | - | - | 1,882,057 | 108,509 | 468,293 | 2,458,859 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Nolands River** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 2,024 | 149,776 | - | 113,096 | 262,872 |
| Field Diversions | Acre | 58 | 12,528 | - | 5,717 | 18,245 |
| Farm and Group Waterways | Mile | 54 | 2,732 | - | 9,412 | 12,144 |
| Gully Stabilization | Mile | 5 | 2,745 | - | 1,012 | 3,757 |
| Improvement and Management of Existing Grassland | Acre | 81,250 | 90,780 | - | 195,565 | 286,345 |
| Technical Services | - | - | 197,580 | - | - | 197,580 |
| Educational Assistance | - | - | 8,565 | 8,565 | - | 17,130 |
| Administrative Cost of Direct Aids | - | - | 14,070 | - | - | 14,070 |
| Total | - | - | 478,776 | 8,565 | 324,802 | 812,143 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 478,776 | 8,565 | 324,802 | 812,143 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| | | **Aquilla Creek** | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 3,503 | 259,222 | - | 222,413 | 481,635 |
| Field Diversions | Acre | 58 | 12,528 | - | 5,932 | 18,460 |
| Farm and Group Waterways | Mile | 257 | 8,407 | - | 28,957 | 37,364 |
| Gully Stabilization | Mile | 65 | 24,220 | - | 26,900 | 51,120 |
| Establishment of New Grassland | Acre | 4,511 | 27,066 | - | 80,160 | 107,226 |
| Improvement and Management of Existing Grassland | Acre | 27,237 | 87,694 | - | 222,106 | 309,800 |
| Technical Services | - | - | 385,305 | - | - | 385,305 |
| Educational Assistance | - | - | 15,030 | 15,030 | - | 30,060 |
| Administrative Cost of Direct Aids | - | - | 24,705 | - | - | 24,705 |
| Total | - | - | 844,177 | 15,030 | 586,468 | 1,445,675 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 30 | 1,577,636 | 636,900 | 63,800 | 2,278,336 |
| Total | - | - | 1,577,636 | 636,900 | 63,800 | 2,278,336 |
| Grand Total | - | - | 2,421,813 | 651,930 | 650,268 | 3,724,011 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| | | Bosque River | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 3,943 | 241,469 | - | 266,293 | 507,762 |
| Field Diversions | Acre | 16 | 1,732 | - | 1,418 | 3,150 |
| Farm and Group Waterways | Mile | 10 | 512 | - | 1,768 | 2,280 |
| Gully Stabilization | Mile | 361 | 186,910 | - | 198,086 | 384,996 |
| Establishment of New Grassland | Acre | 18,747 | 112,482 | - | 601,216 | 713,698 |
| Improvement and Management of Existing Grassland | Acre | 60,995 | 349,493 | - | 513,060 | 862,553 |
| Technical Services | - | - | 825,000 | - | - | 825,000 |
| Educational Assistance | - | - | 35,250 | 35,250 | - | 70,500 |
| Administrative Cost of Direct Aids | - | - | 32,490 | - | - | 32,490 |
| Total | - | - | 1,785,338 | 32,250 | 1,581,841 | 3,402,429 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 61 | 4,591,371 | 648,750 | 229,000 | 5,469,121 |
| Total | - | - | 4,591,371 | 648,750 | 229,000 | 5,469,121 |
| Grand Total | - | - | 6,376,709 | 684,000 | 1,810,841 | 8,871,550 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Whitney to Waco** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 1,498 | 110,852 | - | 85,024 | 195,876 |
| Field Diversions | Acre | 48 | 10,368 | - | 4,747 | 15,115 |
| Farm and Group Waterways | Mile | 49 | 2,198 | - | 7,572 | 9,770 |
| Gully Stabilization | Mile | 5 | 2,440 | - | 900 | 3,340 |
| Establishment of New Grassland | Acre | 298 | 1,788 | - | 5,295 | 7,083 |
| Improvement and Management of Existing Grassland | Acre | 5,447 | 79,583 | - | 172,710 | 252,293 |
| Technical Services | - | - | 159,330 | - | - | 159,330 |
| Educational Assistance | - | - | 7,080 | 7,080 | - | 14,160 |
| Administrative Cost of Direct Aids | - | - | 11,625 | - | - | 11,625 |
| Total | - | - | 385,264 | 7,080 | 276,248 | 668,592 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 3 | 114,354 | 36,900 | 7,200 | 158,454 |
| Total | - | - | 114,354 | 36,900 | 7,200 | 158,454 |
| Grand Total | - | - | 499,618 | 43,980 | 283,448 | 827,046 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Waco to Little River** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 13,204 | 977,096 | - | 813,859 | 1,790,955 |
| Field Diversions | Acre | 242 | 52,272 | - | 25,028 | 77,300 |
| Farm and Group Waterways | Mile | 1,188 | 37,957 | - | 130,739 | 168,696 |
| Gully Stabilization | Mile | 215 | 84,715 | - | 91,712 | 176,427 |
| Establishment of New Grassland | Acre | 83,087 | 245,939 | - | 511,280 | 757,219 |
| Fire Protection | Acre | 13,000 | 2,925 | 975 | - | 3,900 |
| Technical Services | - | - | 1,328,385 | - | - | 1,328,385 |
| Educational Assistance | - | - | 51,367 | 51,368 | - | 102,735 |
| Administrative Cost of Direct Aids | - | - | 84,450 | - | - | 84,450 |
| Total | - | - | 2,975,704 | 52,343 | 1,900,172 | 4,928,219 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 82 | 4,103,671 | 2,255,330 | 158,400 | 6,517,401 |
| Floodway and Channel Improvements | Mile | 40.35 | 610,904 | - | 509,421 | 1,120,325 |
| Total | - | - | 4,714,575 | 2,255,330 | 667,821 | 7,637,726 |
| Grand Total | - | - | 7,690,279 | 2,307,673 | 2,567,993 | 12,565,945 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Little River** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 31,612 | 2,002,936 | - | 2,234,723 | 4,237,659 |
| Field Diversions | Acre | 677 | 90,420 | - | 73,980 | 164,400 |
| Cover Crops | Acre | 193,100 | 531,025 | - | 193,100 | 724,125 |
| Farm and Group Waterways | Mile | 1,120 | 40,226 | - | 138,539 | 178,765 |
| Gully Stabilization | Mile | 976 | 517,908 | - | 425,219 | 943,127 |
| Establishment of New Grassland | Acre | 107,871 | 664,330 | - | 2,911,610 | 3,575,940 |
| Improvement and Management of Existing Grassland | Acre | 234,630 | 1,011,850 | - | 1,693,765 | 2,705,615 |
| Fire Protection | Acre | 51,000 | 11,475 | 3,825 | - | 15,300 |
| Technical Services | - | - | 3,675,000 | - | - | 3,675,000 |
| Educational Assistance | - | - | 159,750 | 159,750 | - | 319,500 |
| Administrative Cost of Direct Aids | - | - | 185,100 | - | - | 185,100 |
| Total | - | - | 8,890,020 | 163,575 | 7,670,936 | 16,724,531 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 287 | 15,595,542 | 4,155,525 | 1,064,200 | 20,815,267 |
| Floodway and Channel Improvements | Mile | 7 | 466,900 | - | 136,700 | 603,600 |
| Total | - | - | 16,062,442 | 4,155,525 | 1,200,900 | 21,418,867 |
| Grand Total | - | - | 24,952,462 | 4,319,100 | 8,871,836 | 38,143,398 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs
of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Little Brazos** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 3,993 | 295,482 | - | 254,697 | 550,179 |
| Field Diversions | Acre | 135 | 29,160 | - | 13,430 | 42,590 |
| Farm and Group Waterways | Mile | 366 | 11,694 | - | 40,278 | 51,972 |
| Gully Stabilization | Mile | 13 | 17,690 | - | 6,525 | 24,215 |
| Establishment of New Grassland | Acre | 2,254 | 13,524 | - | 40,054 | 53,578 |
| Improvement and Management of Existing Grassland | Acre | 40,809 | 153,547 | - | 450,691 | 604,238 |
| Fire Protection | Acre | 42,000 | 9,450 | 3,150 | - | 12,600 |
| Technical Services | - | - | 379,110 | - | - | 379,110 |
| Educational Assistance | - | - | 19,545 | 19,545 | - | 39,090 |
| Administrative Cost of Direct Aids | - | - | 32,130 | - | - | 32,130 |
| Total | - | - | 961,332 | 22,695 | 805,675 | 1,789,702 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 29 | 1,735,792 | 427,373 | 69,400 | 2,232,565 |
| Total | - | - | 1,735,792 | 427,373 | 69,400 | 2,232,565 |
| Grand Total | - | - | 2,697,124 | 450,068 | 875,075 | 4,022,267 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal (dollars) | Public (dollars) | Private (dollars) | Total (dollars) |
| **Navasota Above Dam** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 7,170 | 530,580 | - | 459,690 | 990,270 |
| Field Diversions | Acre | 134 | 28,944 | - | 13,466 | 42,410 |
| Farm and Group Waterways | Mile | 451 | 14,409 | - | 49,633 | 64,042 |
| Gully Stabilization | Mile | 105 | 76,740 | - | 47,400 | 124,140 |
| Establishment of New Grassland | Acre | 7,368 | 44,208 | - | 130,929 | 175,137 |
| Improvement and Management of Existing Grassland | Acre | 121,605 | 441,104 | - | 1,282,536 | 1,723,640 |
| Fire Protection | Acre | 130,000 | 29,250 | 9,750 | - | 39,000 |
| Technical Services | - | - | 720,555 | - | - | 720,555 |
| Educational Assistance | - | - | 45,525 | 45,525 | - | 91,050 |
| Administrative Cost of Direct Aids | - | - | 74,820 | - | - | 74,820 |
| Total | - | - | 2,006,135 | 55,275 | 1,983,654 | 4,045,064 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 27 | 1,029,168 | 332,100 | 65,400 | 1,426,668 |
| Floodway and Channel Improvements | Mile | 33.6 | 584,033 | - | 512,967 | 1,097,000 |
| Total | - | - | 1,613,201 | 332,100 | 578,367 | 2,523,668 |
| Grand Total | - | - | 3,619,336 | 387,375 | 2,562,021 | 6,568,732 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs: Federal | Costs: Non-Federal: Public | Costs: Non-Federal: Private | Total |
|---|---|---|---|---|---|---|
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Navasota Below Dam** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 1,440 | 106,560 | - | 95,076 | 201,636 |
| Field Diversions | Acre | 48 | 10,368 | - | 4,872 | 15,240 |
| Farm and Group Waterways | Mile | 85 | 2,716 | - | 9,354 | 12,070 |
| Gully Stabilization | Mile | 10 | 12,810 | - | 4,725 | 17,535 |
| Establishment of New Grass-land | Acre | 521 | 3,126 | - | 9,258 | 12,384 |
| Improvement and Management of Existing Grassland | Acre | 31,889 | 116,813 | - | 322,676 | 439,489 |
| Fire Protection | Acre | 51,000 | 11,475 | 3,825 | - | 15,300 |
| Technical Services | - | - | 158,940 | - | - | 158,940 |
| Educational Assistance | - | - | 10,110 | 10,110 | - | 20,220 |
| Administrative Cost of Direct Aids | - | - | 16,620 | - | - | 16,620 |
| Total | - | - | 449,538 | 13,935 | 445,961 | 909,434 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 449,538 | 13,935 | 445,961 | 909,434 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| | | Yegua Above Dam | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 9,329 | 690,346 | - | 641,537 | 1,331,883 |
| Field Diversions | Acre | 204 | 44,064 | - | 19,906 | 63,970 |
| Farm and Group Waterways | Mile | 170 | 5,432 | - | 18,709 | 24,141 |
| Gully Stabilization | Mile | 25 | 34,160 | - | 12,600 | 46,760 |
| Establishment of New Grass-land | Acre | 1,048 | 6,288 | - | 18,623 | 24,911 |
| Improvement and Management of Existing Grassland | Acre | 59,014 | 225,597 | - | 591,873 | 817,470 |
| Fire Protection | Acre | 83,000 | 18,675 | 6,225 | - | 24,900 |
| Technical Services | - | - | 1,018,710 | - | - | 1,018,710 |
| Educational Assistance | - | - | 34,358 | 34,357 | - | 68,715 |
| Administrative Cost of Direct Aids | - | - | 56,475 | - | - | 56,475 |
| Total | - | - | 2,134,105 | 40,582 | 1,303,248 | 3,477,935 |
| Independent Measures | | | | | | |
| Floodwater Retarding Structures | Each | 12 | 902,342 | 184,000 | 30,000 | 1,116,342 |
| Total | - | - | 902,342 | 184,000 | 30,000 | 1,116,342 |
| Grand Total | - | - | 3,036,447 | 224,582 | 1,333,248 | 4,594,277 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices) Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Yegua Below Dam** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 2,653 | 196,322 | - | 181,561 | 377,883 |
| Field Diversions | Acre | 62 | 13,392 | - | 6,088 | 19,480 |
| Farm and Group Waterways | Mile | 61 | 1,949 | - | 6,713 | 8,662 |
| Gully Stabilization | Mile | 8 | 10,370 | - | 3,825 | 14,195 |
| Establishment of New Grassland | Acre | 376 | 2,256 | - | 6,682 | 8,938 |
| Improvement and Management of Existing Grassland | Acre | 40,837 | 62,814 | - | 175,078 | 237,892 |
| Fire Protection | Acre | 43,000 | 9,675 | 3,225 | - | 12,900 |
| Technical Services | - | - | 287,565 | - | - | 287,565 |
| Educational Assistance | - | - | 9,922 | 9,923 | - | 19,845 |
| Administrative Cost of Direct Aids | - | - | 16,305 | - | - | 16,305 |
| Total | - | - | 610,570 | 13,148 | 379,947 | 1,003,665 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 610,570 | 13,148 | 379,947 | 1,003,665 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Mill Creek** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 2,757 | 204,018 | - | 175,647 | 379,665 |
| Field Diversions | Acre | 122 | 26,352 | - | 12,568 | 38,920 |
| Farm and Group Waterways | Mile | 257 | 8,211 | - | 28,283 | 36,494 |
| Gully Stabilization | Mile | 5 | 3,660 | - | 1,350 | 5,010 |
| Establishment of New Grassland | Acre | 1,565 | 9,390 | - | 27,810 | 37,200 |
| Improvement and Management of Existing Grassland | Acre | 33,118 | 110,509 | - | 224,500 | 335,009 |
| Fire Protection | Acre | 17,000 | 3,825 | 1,275 | - | 5,100 |
| Technical Services | - | - | 310,485 | - | - | 310,485 |
| Educational Assistance | - | - | 12,323 | 12,322 | - | 24,645 |
| Administrative Cost of Direct Aids | - | - | 20,265 | - | - | 20,265 |
| Total | - | - | 709,038 | 13,597 | 470,158 | 1,192,793 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 709,038 | 13,597 | 470,158 | 1,192,793 |

Table 40 (continued) - Quantities of Measures and Distribution of Installation Costs
of the Recommended Program (1949 Prices)
Brazos River, Texas

| Measure | Unit | Quantity | Costs | | | |
|---|---|---|---|---|---|---|
| | | | | Non-Federal | | |
| | | | Federal | Public | Private | Total |
| | | | (dollars) | (dollars) | (dollars) | (dollars) |
| **Little River to Irrigation** | | | | | | |
| Land Treatment Measures | | | | | | |
| Terraces | Mile | 6,735 | 498,390 | - | 442,866 | 941,256 |
| Field Diversions | Acre | 251 | 54,216 | - | 25,404 | 79,620 |
| Farm and Group Waterways | Mile | 421 | 13,450 | - | 46,331 | 59,781 |
| Gully Stabilization | Mile | 20 | 20,130 | - | 7,425 | 27,555 |
| Establishment of New Grassland | Acre | 2,597 | 15,582 | - | 46,149 | 61,731 |
| Improvement and Management of Existing Grassland | Acre | 71,778 | 252,180 | - | 578,309 | 830,489 |
| Fire Protection | Acre | 70,000 | 15,750 | 5,250 | - | 21,000 |
| Technical Services | - | - | 540,885 | - | - | 540,885 |
| Educational Assistance | - | - | 29,587 | 29,588 | - | 59,175 |
| Administrative Cost of Direct Aids | - | - | 48,630 | - | - | 48,630 |
| Total | - | - | 1,488,800 | 34,838 | 1,146,484 | 2,670,122 |
| Independent Measures | - | - | - | - | - | - |
| Grand Total | - | - | 1,488,800 | 34,838 | 1,146,484 | 2,670,122 |

Table 41. Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Total Brazos River Watershed** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 1,539,523 | 202,511 | - | 291,789 | 202,511 | - | 1,831,312 | 2,033,823 |
| Field Diversions | - | - | 26,984 | 14,683 | - | 12,490 | 14,683 | - | 39,474 | 54,157 |
| Cover Crops | - | - | - | 13,277 | - | 7,724 | 13,277 | - | 7,724 | 21,001 |
| Farm and Group Waterways | - | - | 31,066 | 4,508 | - | 24,850 | 4,508 | - | 55,916 | 60,424 |
| Gully Stabilization | - | - | 83,208 | 43,760 | - | 44,259 | 43,760 | - | 127,467 | 171,227 |
| Establishment of New Grassland | - | - | 129,215 | 32,350 | - | 218,855 | 32,350 | - | 348,070 | 380,420 |
| Improvement and Management of Existing Grassland | - | - | - | 163,806 | - | 497,253 | 163,806 | - | 497,253 | 661,059 |
| Fire Protection | 7,500 | 2,500 | - | 2,813 | 938 | - | 10,313 | 3,438 | - | 13,751 |
| Technical Services | - | - | - | 354,865 | - | - | 354,865 | - | - | 354,865 |
| Educational Assistance | - | - | - | 16,407 | 16,407 | - | 16,407 | 16,407 | - | 32,814 |
| Administrative Cost of Direct Aids | - | - | - | 24,393 | - | - | 24,393 | - | - | 24,393 |
| Total | 7,500 | 2,500 | 1,809,996 | 873,373 | 17,345 | 1,097,220 | 880,873 | 19,845 | 2,907,216 | 3,807,934 |
| Independent Measures | | | | | | | | | | |
| Floodwater Retarding Structures | - | - | 111,600 | 873,064 | 222,105 | 74,113 | 873,064 | 222,105 | 185,713 | 1,280,882 |
| Floodway and Channel Improvements | - | - | 75,584 | 41,548 | - | 46,363 | 41,548 | - | 121,947 | 163,495 |
| Total | - | - | 187,184 | 914,612 | 222,105 | 120,476 | 914,612 | 222,105 | 307,660 | 1,444,377 |
| Grand Total | 7,500 | 2,500 | 1,997,180 | 1,787,985 | 239,450 | 1,217,696 | 1,795,485 | 241,950 | 3,214,876 | 5,252,311 |

1/ Includes interest on installation cost plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Salt Fork** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Farm and Group Waterways | 91 | 13 | - | 72 | 13 | - | 163 | 176 |
| Establishment of New Grassland | 629 | 192 | - | 1,818 | 192 | - | 2,447 | 2,639 |
| Improvement and Management of Existing Grassland | - | 496 | - | 474 | 496 | - | 474 | 970 |
| Technical Services | - | 62 | - | - | 62 | - | - | 62 |
| Educational Assistance | - | 33 | 32 | - | 33 | 32 | - | 65 |
| Administrative Cost of Direct Aids | - | 53 | - | - | 53 | - | - | 53 |
| Total | 720 | 849 | 32 | 2,364 | 849 | 32 | 3,084 | 3,965 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 720 | 849 | 32 | 2,364 | 849 | 32 | 3,084 | 3,965 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Brazos Above Possum Kingdom** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 41,441 | 6,199 | - | 6,659 | 6,199 | - | 48,100 | 54,299 |
| Field Diversions | 733 | 400 | - | 337 | 400 | - | 1,070 | 1,470 |
| Farm and Group Waterways | 259 | 38 | - | 207 | 38 | - | 466 | 504 |
| Establishment of New Grassland | 1,164 | 355 | - | 3,364 | 355 | - | 4,528 | 4,883 |
| Improvement and Management of Existing Grassland | - | 9,485 | - | 20,385 | 9,485 | - | 20,385 | 29,870 |
| Technical Services | - | 3,704 | - | - | 3,704 | - | - | 3,704 |
| Educational Assistance | - | 519 | 519 | - | 519 | 519 | - | 1,038 |
| Administrative Cost of Direct Aids | - | 854 | - | - | 854 | - | - | 854 |
| Total | 43,597 | 21,554 | 519 | 30,952 | 21,554 | 519 | 74,549 | 96,622 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 43,597 | 21,554 | 519 | 30,952 | 21,554 | 519 | 74,549 | 96,622 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **California Creek** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Farm and Group Waterways | 518 | 75 | - | 414 | 75 | - | 932 | 1,007 |
| Establishment of New Grassland | 3,372 | 1,047 | - | 9,810 | 1,047 | - | 13,182 | 14,229 |
| Improvement and Management of Existing Grassland | - | 1,946 | - | 4,961 | 1,946 | - | 4,961 | 6,907 |
| Technical Services | - | 269 | - | - | 269 | - | - | 269 |
| Educational Assistance | - | 186 | 186 | - | 186 | 186 | - | 372 |
| Administrative Cost of Direct Aids | - | 306 | - | - | 306 | - | - | 306 |
| Total | 3,890 | 3,829 | 186 | 15,185 | 3,829 | 186 | 19,075 | 23,090 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 3,890 | 3,829 | 186 | 15,185 | 3,829 | 186 | 19,075 | 23,090 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Elm Creek** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Farm and Group Waterways | 181 | 26 | - | 145 | 26 | - | 326 | 352 |
| Establishment of New Grassland | 1,221 | 397 | - | 3,613 | 397 | - | 4,834 | 5,231 |
| Improvement and Management of Existing Grassland | - | 1,897 | - | 5,747 | 1,897 | - | 5,747 | 7,644 |
| Technical Services | - | 213 | - | - | 213 | - | - | 213 |
| Educational Assistance | - | 120 | 119 | - | 120 | 119 | - | 239 |
| Administrative Cost of Direct Aids | - | 196 | - | - | 196 | - | - | 196 |
| Total | 1,402 | 2,849 | 119 | 9,505 | 2,849 | 119 | 10,907 | 13,875 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 1,402 | 2,849 | 119 | 9,505 | 2,849 | 119 | 10,907 | 13,875 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Hubbard Creek** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 60,922 | 9,112 | - | 9,789 | 9,112 | - | 70,711 | 79,823 |
| Field Diversions | 1,089 | 594 | - | 502 | 594 | - | 1,591 | 2,185 |
| Farm and Group Waterways | 1,255 | 182 | - | 1,004 | 182 | - | 2,259 | 2,441 |
| Establishment of New Grassland | - | 31 | - | 105 | 31 | - | 105 | 136 |
| Improvement and Management of Existing Grassland | - | 14,593 | - | 35,377 | 14,593 | - | 35,377 | 49,970 |
| Technical Services | - | 19,935 | - | - | 19,935 | - | - | 19,935 |
| Educational Assistance | - | 774 | 774 | - | 774 | 774 | - | 1,548 |
| Administrative Cost of Direct Aids | - | 1,272 | - | - | 1,272 | - | - | 1,272 |
| Total | 63,266 | 46,493 | 774 | 46,777 | 46,493 | 774 | 110,043 | 157,310 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 63,266 | 46,493 | 774 | 46,777 | 46,493 | 774 | 110,043 | 157,310 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Clear Fork** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 21,528 | 3,220 | - | 3,459 | 3,220 | - | 24,987 | 28,207 |
| Field Diversions | 386 | 211 | - | 178 | 211 | - | 564 | 775 |
| Farm and Group Waterways | 984 | 143 | - | 787 | 143 | - | 1,771 | 1,914 |
| Establishment of New Grassland | 5,931 | 1,952 | - | 17,630 | 1,952 | - | 23,561 | 25,513 |
| Improvement and Management of Existing Grassland | - | 15,246 | - | 43,306 | 15,246 | - | 43,306 | 58,552 |
| Technical Services | - | 3,066 | - | - | 3,066 | - | - | 3,066 |
| Educational Assistance | - | 887 | 888 | - | 887 | 888 | - | 1,775 |
| Administrative Cost of Direct Aids | - | 1,458 | - | - | 1,458 | - | - | 1,458 |
| Total | 28,829 | 26,183 | 888 | 65,360 | 26,183 | 888 | 94,189 | 121,260 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 28,829 | 26,183 | 888 | 65,360 | 26,183 | 888 | 94,189 | 121,260 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Possum Kingdom | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 48,479 | 7,201 | - | 7,869 | 7,201 | - | 56,348 | 63,549 |
| Field Diversions | 1,460 | 815 | - | 642 | 815 | - | 2,102 | 2,917 |
| Farm and Group Waterways | 277 | 40 | - | 221 | 40 | - | 498 | 538 |
| Gully Stabilization | 827 | 503 | - | 297 | 503 | - | 1,124 | 1,627 |
| Establishment of New Grassland | 190 | 82 | - | 376 | 82 | - | 566 | 648 |
| Improvement and Management of Existing Grassland | - | 8,852 | - | 21,020 | 8,852 | - | 21,020 | 29,872 |
| Technical Services | - | 13,001 | - | - | 13,001 | - | - | 13,001 |
| Educational Assistance | - | 531 | 530 | - | 531 | 530 | - | 1,061 |
| Administrative Cost of Direct Aids | - | 872 | - | - | 872 | - | - | 872 |
| Total | 51,233 | 31,897 | 530 | 30,425 | 31,897 | 530 | 81,658 | 114,085 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 51,233 | 31,897 | 530 | 30,425 | 31,897 | 530 | 81,658 | 114,085 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program(1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| | | | | | | | | |
| Possum Kingdom to Whitney | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 96,590 | 13,651 | - | 16,794 | 13,651 | - | 113,384 | 127,035 |
| Field Diversions | 3,710 | 2,084 | - | 1,612 | 2,084 | - | 5,322 | 7,406 |
| Farm and Group Waterways | 1,233 | 179 | - | 986 | 179 | - | 2,219 | 2,398 |
| Gully Stabilization | 23,296 | 14,183 | - | 8,370 | 14,183 | - | 31,666 | 45,849 |
| Establishment of New Grassland | 5,283 | 2,272 | - | 10,454 | 2,272 | - | 15,737 | 18,009 |
| Improvement and Management of Existing Grassland | - | 21,108 | - | 62,739 | 21,108 | - | 62,739 | 83,847 |
| Technical Services | - | 46,613 | - | - | 46,613 | - | - | 46,613 |
| Educational Assistance | - | 1,707 | 1,708 | - | 1,707 | 1,708 | - | 3,415 |
| Administrative Cost of Direct Aids | - | 2,803 | - | - | 2,803 | - | - | 2,803 |
| Total | 130,112 | 104,600 | 1,708 | 100,955 | 104,600 | 1,708 | 231,067 | 337,375 |
| Independent Measures | | | | | | | | |
| Floodwater Retarding Structures | 2,400 | 29,345 | 2,735 | 2,344 | 29,345 | 2,735 | 4,744 | 36,824 |
| Total | 2,400 | 29,345 | 2,735 | 2,344 | 29,345 | 2,735 | 4,744 | 36,824 |
| Grand Total | 132,512 | 133,945 | 4,443 | 103,299 | 133,945 | 4,443 | 235,811 | 374,199 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Palo Pinto** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 30,475 | 4,439 | - | 5,087 | 4,439 | - | 35,562 | 40,001 |
| Field Diversions | 836 | 464 | - | 371 | 464 | - | 1,207 | 1,671 |
| Farm and Group Waterways | 190 | 28 | - | 152 | 28 | - | 342 | 370 |
| Gully Stabilization | 3,557 | 2,166 | - | 1,278 | 2,166 | - | 4,835 | 7,001 |
| Establishment of New Grassland | 802 | 345 | - | 1,587 | 345 | - | 2,389 | 2,734 |
| Improvement and Management of Existing Grassland | - | 6,269 | - | 16,202 | 6,269 | - | 16,202 | 22,471 |
| Technical Services | - | 11,172 | - | - | 11,172 | - | - | 11,172 |
| Educational Assistance | - | 425 | 424 | - | 425 | 424 | - | 849 |
| Administrative Cost of Direct Aids | - | 698 | - | - | 698 | - | - | 698 |
| Total | 35,860 | 26,006 | 424 | 24,677 | 26,006 | 424 | 60,537 | 86,967 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 35,860 | 26,006 | 424 | 24,677 | 26,006 | 424 | 60,537 | 86,967 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Paluxy Creek** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 15,135 | 2,113 | - | 2,674 | 2,113 | - | 17,809 | 19,922 |
| Field Diversions | 803 | 454 | - | 345 | 454 | - | 1,148 | 1,602 |
| Farm and Group Waterways | 262 | 38 | - | 210 | 38 | - | 472 | 510 |
| Gully Stabilization | 3,357 | 2,044 | - | 1,206 | 2,044 | - | 4,563 | 6,607 |
| Establishment of New Grassland | 953 | 410 | - | 1,885 | 410 | - | 2,838 | 3,248 |
| Improvement and Management of Existing Grassland | - | 3,036 | - | 9,678 | 3,036 | - | 9,678 | 12,714 |
| Technical Services | - | 7,157 | - | - | 7,157 | - | - | 7,157 |
| Educational Assistance | - | 265 | 266 | - | 265 | 266 | - | 531 |
| Administrative Cost of Direct Aids | - | 436 | - | - | 436 | - | - | 436 |
| Total | 20,510 | 15,953 | 266 | 15,998 | 15,953 | 266 | 36,508 | 52,727 |
| Independent Measures | | | | | | | | |
| Floodwater Retarding Structures | 3,000 | 33,975 | 2,447 | 2,765 | 33,975 | 2,447 | 5,765 | 42,187 |
| Total | 3,000 | 33,975 | 2,447 | 2,765 | 33,975 | 2,447 | 5,765 | 42,187 |
| Grand Total | 23,510 | 49,928 | 2,713 | 18,763 | 49,928 | 2,713 | 42,273 | 94,914 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Nolands River** | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 26,287 | 3,744 | - | 4,524 | 3,744 | - | 30,811 | 34,555 |
| Field Diversions | 547 | 313 | - | 229 | 313 | - | 776 | 1,089 |
| Farm and Group Waterways | 471 | 68 | - | 376 | 68 | - | 847 | 915 |
| Gully Stabilization | 113 | 69 | - | 40 | 69 | - | 153 | 222 |
| Improvement and Management of Existing Grassland | - | 2,267 | - | 7,822 | 2,267 | - | 7,822 | 10,089 |
| Technical Services | - | 4,940 | - | - | 4,940 | - | - | 4,940 |
| Educational Assistance | - | 214 | 214 | - | 214 | 214 | - | 428 |
| Administrative Cost of Direct Aids | - | 352 | - | - | 352 | - | - | 352 |
| Total | 27,418 | 11,967 | 214 | 12,991 | 11,967 | 214 | 40,409 | 52,590 |
| Independent Measures | - | - | - | - | - | - | - | - |
| Grand Total | 27,418 | 11,967 | 214 | 12,991 | 11,967 | 214 | 40,409 | 52,590 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Aquilla Creek | | | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 48,164 | 6,481 | - | 8,897 | 6,481 | - | 57,061 | 63,542 |
| Field Diversions | 554 | 313 | - | 237 | 313 | - | 791 | 1,104 |
| Farm and Group Waterways | 1,448 | 210 | - | 1,158 | 210 | - | 2,606 | 2,816 |
| Gully Stabilization | 1,534 | 606 | - | 1,076 | 606 | - | 2,610 | 3,216 |
| Establishment of New Grassland | 1,110 | 677 | - | 3,206 | 677 | - | 4,316 | 4,993 |
| Improvement and Management of Existing Grassland | - | 2,193 | - | 8,884 | 2,193 | - | 8,884 | 11,077 |
| Technical Services | - | 9,633 | - | - | 9,633 | - | - | 9,633 |
| Educational Assistance | - | 376 | 376 | - | 376 | 376 | - | 752 |
| Administrative Cost of Direct Aids | - | 618 | - | - | 618 | - | - | 618 |
| Total | 52,810 | 21,107 | 376 | 23,458 | 21,107 | 376 | 76,268 | 97,751 |
| Independent Measures | | | | | | | | |
| Floodwater Retarding Structures | 6,000 | 43,084 | 15,923 | 2,604 | 43,084 | 15,923 | 8,604 | 67,611 |
| Total | 6,000 | 43,084 | 15,923 | 2,604 | 43,084 | 15,923 | 8,604 | 67,611 |
| Grand Total | 58,810 | 64,191 | 16,299 | 26,062 | 64,191 | 16,299 | 84,872 | 165,362 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| | | **Bosque** | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 50,776 | 6,036 | - | 10,651 | 6,036 | - | 61,427 | 67,463 |
| Field Diversions | 95 | 44 | - | 57 | 44 | - | 152 | 196 |
| Farm and Group Waterways | 88 | 12 | - | 70 | 12 | - | 158 | 170 |
| Gully Stabilization | 9,055 | 4,673 | - | 7,924 | 4,673 | - | 16,979 | 21,652 |
| Establishment of New Grassland | 18,016 | 2,812 | - | 24,049 | 2,812 | - | 42,065 | 44,877 |
| Improvement and Management of Existing Grassland | - | 8,738 | - | 20,523 | 8,738 | - | 20,523 | 29,261 |
| Technical Services | - | 20,625 | - | - | 20,625 | - | - | 20,625 |
| Educational Assistance | - | 882 | 881 | - | 882 | 881 | - | 1,763 |
| Administrative Cost of Direct Aids | - | 812 | - | - | 812 | - | - | 812 |
| Total | 78,030 | 44,634 | 881 | 63,274 | 44,634 | 881 | 141,304 | 186,819 |
| Independent Measures | | | | | | | | |
| Floodwater Retarding Structures | 12,200 | 125,392 | 16,219 | 9,423 | 125,392 | 16,219 | 21,623 | 163,234 |
| Total | 12,200 | 125,392 | 16,219 | 9,423 | 125,392 | 16,219 | 21,623 | 163,234 |
| Grand Total | 90,230 | 170,026 | 17,100 | 72,697 | 170,026 | 17,100 | 162,927 | 350,053 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Non-Federal | | | Non-Federal | | |
| | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| | | **Whitney to Waco** | | | | | | |
| Land Treatment Measures | | | | | | | | |
| Terraces | 19,588 | 2,771 | - | 3,401 | 2,771 | - | 22,989 | 25,760 |
| Field Diversions | 453 | 259 | - | 190 | 259 | - | 643 | 902 |
| Farm and Group Waterways | 379 | 55 | - | 303 | 55 | - | 682 | 737 |
| Gully Stabilization | 100 | 61 | - | 36 | 61 | - | 136 | 197 |
| Establishment of New Grassland | 73 | 45 | - | 212 | 45 | - | 285 | 330 |
| Improvement and Management of Existing Grassland | - | 1,989 | - | 6,908 | 1,989 | - | 6,908 | 8,897 |
| Technical Services | - | 3,983 | - | - | 3,983 | - | - | 3,983 |
| Educational Assistance | - | 177 | 177 | - | 177 | 177 | - | 354 |
| Administrative Cost of Direct Aids | - | 291 | - | - | 291 | - | - | 291 |
| Total | 20,593 | 9,631 | 177 | 11,050 | 9,631 | 177 | 31,643 | 41,451 |
| Independent Measures | | | | | | | | |
| Floodwater Retarding Structures | 600 | 3,122 | 923 | 294 | 3,122 | 923 | 894 | 4,939 |
| Total | 600 | 3,122 | 923 | 294 | 3,122 | 923 | 894 | 4,939 |
| Grand Total | 21,193 | 12,753 | 1,100 | 11,344 | 12,753 | 1,100 | 32,537 | 46,390 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars | (dollars) |
| **Waco to Little River** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 179,096 | 24,427 | - | 32,554 | 24,427 | - | 211,650 | 236,077 |
| Field Diversions | - | - | 2,319 | 1,307 | - | 1,001 | 1,307 | - | 3,320 | 4,627 |
| Farm and Group Waterways | - | - | 6,537 | 949 | - | 5,230 | 949 | - | 11,767 | 12,716 |
| Gully Stabilization | - | - | 5,293 | 2,118 | - | 3,668 | 2,118 | - | 8,961 | 11,079 |
| Establishment of New Grassland | - | - | 4,535 | 2,765 | - | 13,102 | 2,765 | - | 17,637 | 20,402 |
| Improvement and Management of Existing Grassland | - | - | - | 6,149 | - | 20,451 | 6,149 | - | 20,451 | 26,600 |
| Fire Protection | 195 | 65 | - | 73 | 24 | - | 268 | 89 | - | 357 |
| Technical Services | - | - | - | 33,210 | - | - | 33,210 | - | - | 33,210 |
| Educational Assistance | - | - | - | 1,284 | 1,284 | - | 1,284 | 1,284 | - | 2,568 |
| Administrative Cost of Direct Aids | - | - | - | 2,111 | - | - | 2,111 | - | - | 2,111 |
| Total | 195 | 65 | 197,780 | 74,393 | 1,308 | 76,006 | 74,588 | 1,373 | 273,786 | 349,747 |
| Independent Measures | | | | | | | | | | |
| Floodwater Retarding Structures | - | - | 16,400 | 112,071 | 56,383 | 6,464 | 112,071 | 56,383 | 22,864 | 191,318 |
| Floodway and Channel Improvements | - | - | 25,143 | 15,274 | - | 20,376 | 15,274 | - | 45,519 | 60,793 |
| Total | - | - | 41,543 | 127,345 | 56,383 | 26,840 | 127,345 | 56,383 | 68,383 | 252,111 |
| Grand Total | 195 | 65 | 239,323 | 201,738 | 57,691 | 102,846 | 201,933 | 57,756 | 342,169 | 601,858 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Federal | Non-Federal Public | Non-Federal Private | Federal | Non-Federal Public | Non-Federal Private | Federal | Non-Federal Public | Non-Federal Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Little River** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 423,764 | 50,074 | - | 89,389 | 50,074 | - | 513,153 | 563,227 |
| Field Diversions | - | - | 4,932 | 2,262 | - | 2,959 | 2,262 | - | 7,891 | 10,153 |
| Cover Crops | - | - | - | 13,277 | - | 7,724 | 13,277 | - | 7,724 | 21,001 |
| Farm and Group Waterways | - | - | 6,927 | 1,006 | - | 5,544 | 1,006 | - | 12,471 | 13,477 |
| Gully Stabilization | - | - | 28,294 | 12,948 | - | 17,010 | 12,948 | - | 45,304 | 58,252 |
| Establishment of New Grassland | - | - | 81,994 | 16,609 | - | 116,465 | 16,609 | - | 198,459 | 215,068 |
| Improvement and Management of Existing Grassland | - | - | - | 25,297 | - | 67,751 | 25,297 | - | 67,751 | 93,048 |
| Fire Protection | 765 | 255 | - | 287 | 95 | - | 1,052 | 350 | - | 1,402 |
| Technical Services | - | - | - | 91,875 | - | - | 91,875 | - | - | 91,875 |
| Educational Assistance | - | - | - | 3,994 | 3,994 | - | 3,994 | 3,994 | - | 7,988 |
| Administrative Cost of Direct Aids | - | - | - | 4,628 | - | - | 4,628 | - | - | 4,628 |
| Total | 765 | 255 | 545,911 | 222,257 | 4,089 | 306,842 | 223,022 | 4,344 | 852,753 | 1,080,119 |
| Independent Measures | | | | | | | | | | |
| Floodwater Retarding Structures | - | - | 57,400 | 425,921 | 103,888 | 43,494 | 425,921 | 103,888 | 100,894 | 630,703 |
| Floodway and Channel Improvements | - | - | 23,345 | 11,673 | - | 5,468 | 11,673 | - | 28,813 | 40,486 |
| Total | - | - | 80,745 | 437,594 | 103,888 | 48,962 | 437,594 | 103,888 | 129,707 | 671,189 |
| Grand Total | 765 | 255 | 626,656 | 659,851 | 107,977 | 355,804 | 660,616 | 108,232 | 982,460 | 1,751,308 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Little Brazos** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 55,018 | 7,387 | - | 10,187 | 7,387 | - | 65,205 | 72,592 |
| Field Diversions | - | - | 1,278 | 729 | - | 537 | 729 | - | 1,815 | 2,544 |
| Farm and Group Waterways | - | - | 2,014 | 292 | - | 1,611 | 292 | - | 3,625 | 3,917 |
| Gully Stabilization | - | - | 726 | 442 | - | 261 | 442 | - | 987 | 1,429 |
| Establishment of New Grassland | - | - | 555 | 338 | - | 1,602 | 338 | - | 2,157 | 2,495 |
| Improvement and Management of Existing Grassland | - | - | - | 3,838 | - | 18,027 | 3,838 | - | 18,027 | 21,865 |
| Fire Protection | 630 | 210 | - | 236 | 79 | - | 866 | 289 | - | 1,155 |
| Technical Services | - | - | - | 9,478 | - | - | 9,478 | - | - | 9,478 |
| Educational Assistance | - | - | - | 488 | 489 | - | 488 | 489 | - | 977 |
| Administrative Cost of Direct Aids | - | - | - | 803 | - | - | 803 | - | - | 803 |
| Total | 630 | 210 | 59,591 | 24,031 | 568 | 32,225 | 24,661 | 778 | 91,816 | 117,255 |
| Independent Measures | | | | | | | | | | |
| Floodwater Retarding Structures | - | - | 5,800 | 47,405 | 10,684 | 2,832 | 47,405 | 10,684 | 8,632 | 66,721 |
| Total | - | - | 5,800 | 47,405 | 10,684 | 2,832 | 47,405 | 10,684 | 8,632 | 66,721 |
| Grand Total | 630 | 210 | 65,391 | 71,436 | 11,252 | 35,057 | 72,066 | 11,462 | 100,448 | 183,976 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Navasota Above Dam** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 99,027 | 13,265 | - | 18,388 | 13,265 | - | 117,415 | 130,680 |
| Field Diversions | - | - | 1,272 | 724 | - | 539 | 724 | - | 1,811 | 2,535 |
| Farm and Group Waterways | - | - | 2,482 | 360 | - | 1,985 | 360 | - | 4,467 | 4,827 |
| Gully Stabilization | - | - | 3,724 | 1,919 | - | 1,896 | 1,919 | - | 5,620 | 7,539 |
| Establishment of New Grassland | - | - | 1,813 | 1,105 | - | 5,237 | 1,105 | - | 7,050 | 8,155 |
| Improvement and Management of Existing Grassland | - | - | - | 11,207 | - | 51,301 | 11,207 | - | 51,301 | 62,508 |
| Fire Protection | 1,950 | 650 | - | 731 | 244 | - | 2,681 | 894 | - | 3,575 |
| Technical Services | - | - | - | 18,014 | - | - | 18,014 | - | - | 18,014 |
| Educational Assistance | - | - | - | 1,138 | 1,138 | - | 1,138 | 1,138 | - | 2,276 |
| Administrative Cost of Direct Aids | - | - | - | 1,871 | - | - | 1,871 | - | - | 1,871 |
| Total | 1,950 | 650 | 108,318 | 50,334 | 1,382 | 79,346 | 52,284 | 2,032 | 187,664 | 241,980 |
| Independent Measures | | | | | | | | | | |
| Floodwater Retarding Structures | - | - | 5,400 | 28,106 | 8,303 | 2,669 | 28,106 | 8,303 | 8,069 | 44,478 |
| Floodway and Channel Improvements | - | - | 27,096 | 14,601 | - | 20,519 | 14,601 | - | 47,615 | 62,216 |
| Total | - | - | 32,496 | 42,707 | 8,303 | 23,188 | 42,707 | 8,303 | 55,684 | 106,694 |
| Grand Total | 1,950 | 650 | 140,814 | 93,041 | 9,685 | 102,534 | 94,991 | 10,335 | 243,348 | 348,674 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Navasota Below Dam** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 20,164 | 2,664 | - | 3,803 | 2,664 | - | 23,967 | 26,631 |
| Field Diversions | - | - | 457 | 259 | - | 195 | 259 | - | 652 | 911 |
| Farm and Group Waterways | - | - | 468 | 68 | - | 374 | 68 | - | 842 | 910 |
| Gully Stabilization | - | - | 526 | 320 | - | 189 | 320 | - | 715 | 1,035 |
| Establishment of New Grassland | - | - | 128 | 78 | - | 370 | 78 | - | 498 | 576 |
| Improvement and Management of Existing Grassland | - | - | - | 2,921 | - | 12,907 | 2,921 | - | 12,907 | 15,828 |
| Fire Protection | 765 | 255 | - | 287 | 96 | - | 1,052 | 351 | - | 1,403 |
| Technical Services | - | - | - | 3,974 | - | - | 3,974 | - | - | 3,974 |
| Educational Assistance | - | - | - | 253 | 253 | - | 253 | 253 | - | 506 |
| Administrative Cost of Direct Aids | - | - | - | 416 | - | - | 416 | - | - | 416 |
| Total | 765 | 255 | 21,743 | 11,240 | 349 | 17,838 | 12,005 | 604 | 39,581 | 52,190 |
| Independent Measures | - | - | - | - | - | - | - | - | - | - |
| Grand Total | 765 | 255 | 21,743 | 11,240 | 349 | 17,838 | 12,005 | 604 | 39,581 | 52,190 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Yegua Above Dam** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 133,188 | 17,259 | - | 25,661 | 17,259 | - | 158,849 | 176,108 |
| Field Diversions | - | - | 1,919 | 1,102 | - | 796 | 1,102 | - | 2,715 | 3,817 |
| Farm and Group Waterways | - | - | 935 | 136 | - | 748 | 136 | - | 1,683 | 1,819 |
| Gully Stabilization | - | - | 1,403 | 854 | - | 504 | 854 | - | 1,907 | 2,761 |
| Establishment of New Grassland | - | - | 258 | 157 | - | 745 | 157 | - | 1,003 | 1,160 |
| Improvement and Management of Existing Grassland | - | - | - | 5,640 | - | 23,674 | 5,640 | - | 23,674 | 29,314 |
| Fire Protection | 1,245 | 415 | - | 467 | 156 | - | 1,712 | 571 | - | 2,283 |
| Technical Services | - | - | - | 25,468 | - | - | 25,468 | - | - | 25,468 |
| Educational Assistance | - | - | - | 859 | 859 | - | 859 | 859 | - | 1,718 |
| Administrative Cost of Direct Aids | - | - | - | 1,412 | - | - | 1,412 | - | - | 1,412 |
| Total | 1,245 | 415 | 137,703 | 53,354 | 1,015 | 52,128 | 54,599 | 1,430 | 189,831 | 245,860 |
| Independent Measures | | | | | | | | | | |
| Floodwater Retarding Structures | - | - | 2,400 | 24,643 | 4,600 | 1,224 | 24,643 | 4,600 | 3,624 | 32,867 |
| Total | - | - | 2,400 | 24,643 | 4,600 | 1,224 | 24,643 | 4,600 | 3,624 | 32,867 |
| Grand Total | 1,245 | 415 | 140,103 | 77,997 | 5,615 | 53,352 | 79,242 | 6,030 | 193,455 | 278,727 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Yegua Below Dam** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 37,788 | 4,908 | - | 7,262 | 4,908 | - | 45,050 | 49,958 |
| Field Diversions | - | - | 584 | 335 | - | 244 | 335 | - | 828 | 1,163 |
| Farm and Group Waterways | - | - | 336 | 49 | - | 269 | 49 | - | 605 | 654 |
| Gully Stabilization | - | - | 426 | 259 | - | 153 | 259 | - | 579 | 838 |
| Establishment of New Grassland | - | - | 93 | 56 | - | 267 | 56 | - | 360 | 416 |
| Improvement and Management of Existing Grassland | - | - | - | 1,571 | - | 7,003 | 1,571 | - | 7,003 | 8,574 |
| Fire Protection | 645 | 215 | - | 242 | 81 | - | 887 | 296 | - | 1,183 |
| Technical Services | - | - | - | 7,189 | - | - | 7,189 | - | - | 7,189 |
| Educational Assistance | - | - | - | 248 | 248 | - | 248 | 248 | - | 496 |
| Administrative Cost of Direct Aids | - | - | - | 408 | - | - | 408 | - | - | 408 |
| Total | 645 | 215 | 39,227 | 15,265 | 329 | 15,198 | 15,910 | 544 | 54,425 | 70,879 |
| Independent Measures | - | - | - | - | - | - | - | - | - | - |
| Grand Total | 645 | 215 | 39,227 | 15,265 | 329 | 15,198 | 15,910 | 544 | 54,425 | 70,879 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Mill Creek** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 37,967 | 5,100 | - | 7,026 | 5,100 | - | 44,993 | 50,093 |
| Field Diversions | - | - | 1,168 | 659 | - | 503 | 659 | - | 1,671 | 2,330 |
| Farm and Group Waterways | - | - | 1,414 | 205 | - | 1,131 | 205 | - | 2,545 | 2,750 |
| Gully Stabilization | - | - | 150 | 92 | - | 54 | 92 | - | 204 | 296 |
| Establishment of New Grassland | - | - | 456 | 235 | - | 1,112 | 235 | - | 1,568 | 1,803 |
| Improvement and Management of Existing Grassland | - | - | - | 2,763 | - | 8,980 | 2,763 | - | 8,980 | 11,743 |
| Fire Protection | 255 | 85 | - | 96 | 32 | - | 351 | 117 | - | 468 |
| Technical Services | - | - | - | 7,762 | - | - | 7,762 | - | - | 7,762 |
| Educational Assistance | - | - | - | 308 | 308 | - | 308 | 308 | - | 616 |
| Administrative Cost of Direct Aids | - | - | - | 507 | - | - | 507 | - | - | 507 |
| Total | 255 | 85 | 41,155 | 17,727 | 340 | 18,806 | 17,982 | 425 | 59,961 | 78,368 |
| Independent Measures | - | - | - | - | - | - | - | - | - | - |
| Grand Total | 255 | 85 | 41,155 | 17,727 | 340 | 18,806 | 17,982 | 425 | 59,961 | 78,368 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

Table 41 (continued) - Distribution of Average Annual Costs of the Recommended Program (1949 Prices)

Brazos River, Texas

| Measure | Annual Operation and Maintenance Costs | | | Annual Equivalent of Installation Cost 1/ | | | Total Average Annual Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Federal | | | Non-Federal | | | Non-Federal | | |
| | Federal | Public | Private | Federal | Public | Private | Federal | Public | Private | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| **Little River to Irrigation** | | | | | | | | | | |
| Land Treatment Measures | | | | | | | | | | |
| Terraces | - | - | 94,126 | 12,460 | - | 17,715 | 12,460 | - | 111,841 | 124,301 |
| Field Diversions | - | - | 2,389 | 1,355 | - | 1,016 | 1,355 | - | 3,405 | 4,760 |
| Farm and Group Waterways | - | - | 2,317 | 336 | - | 1,853 | 336 | - | 4,170 | 4,506 |
| Gully Stabilization | - | - | 827 | 503 | - | 297 | 503 | - | 1,124 | 1,627 |
| Establishment of New Grassland | - | - | 639 | 390 | - | 1,846 | 390 | - | 2,485 | 2,875 |
| Improvement and Management of Existing Grassland | - | - | - | 6,305 | - | 23,133 | 6,305 | - | 23,133 | 29,438 |
| Fire Protection | 1,050 | 350 | - | 394 | 131 | - | 1,444 | 481 | - | 1,925 |
| Technical Services | - | - | - | 13,522 | - | - | 13,522 | - | - | 13,522 |
| Educational Assistance | - | - | - | 739 | 740 | - | 739 | 740 | - | 1,479 |
| Administrative Cost of Direct Aids | - | - | - | 1,216 | - | - | 1,216 | - | - | 1,216 |
| Total | 1,050 | 350 | 100,298 | 37,220 | 871 | 45,860 | 38,270 | 1,221 | 146,158 | 185,649 |
| Independent Measures | - | - | - | - | - | - | - | - | - | - |
| Grand Total | 1,050 | 350 | 100,298 | 37,220 | 871 | 45,860 | 38,270 | 1,221 | 146,158 | 185,649 |

1/ Includes interest on installation costs plus amortization of construction costs of floodwater retarding structures during a 100-year period.

# LAND TREATMENT MEASURES

The recommended program described herein was designed to alleviate the problems of runoff and waterflow retardation and soil erosion control which exist in the Brazos River Watershed. Field examinations were completed in twelve sample tributaries in the Little and Bosque River Watersheds and in eight additional tributaries in the remaining subwatersheds of the Brazos River Watershed.

Since the land use adjustments and land treatment measures will be applied to the farms and ranches of the watershed by the landowners and operators, it is essential that the measures and practices be planned to accomplish the flood control objectives without unduly disrupting the economy of the area or the individual farm. The measures selected will achieve maximum utilization of the soil to absorb and hold rainfall and will protect the soil from erosion. Soil conservation district officials and regional and field technicians were consulted concerning the practicability and feasibility of the measures recommended.

Nearly all of the Brazos River Watershed is included within organized soil conservation districts (figure 6). The work plans and programs of these districts recommend land use and treatment standards for all lands and reflect the best judgment and most recent information available on soil and water conservation. Application of measures has been in progress for several years and treatment has been initiated on 1,343,500 acres in the Little River, 116,000 acres in the Bosque River and on 5,661,500 acres in the remainder of the Brazos River or a total of 7,121,000 acres.

## Establishment of New Grassland

The major land use adjustment needed in the Brazos River Watershed is the establishment of an adequate grass cover on approximately 1,822,583 acres of land which is now cultivated or lying idle. Approximately 107,870 acres in the Little River, 18,750 acres in the Bosque River and 121,309 acres in the remainder of the Brazos River will be established by the recommended program and 1,574,654 acres in the Brazos River Watershed will be established by the going program. Table 42 shows the land use of the watershed at present and after land-use adjustments have been completed.

## Terraces

All cultivated land subject to water erosion, except deep sandy soils, will be terraced. By decreasing the length of slope on which runoff water travels, terraces greatly reduce sheet erosion and the development of gullies. The low velocity at which runoff water flows

Table 42. Land Use of Farmland at Present (1950) and With Land Treatment Measures Applied.

Brazos River Watershed

| Subwatershed | Total Farmland | Cultivated | | Grassland | | Woodland | | Miscell-aneous | Non-Farm | Total Area |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Present | With Land Treatment | Present | With Land Treatment | Present | With Land Treatment | | | |
| Non-Contributing Area | 3,988,840 | 3,477,850 | 2,277,833 | 487,990 | 1,658,007 | - | - | 53,000 | 119,320 | 4,108,160 |
| White River | 341,140 | 202,335 | 192,803 | 134,715 | 144,247 | - | - | 4,090 | 6,380 | 347,520 |
| Salt Fork | 1,225,640 | 318,462 | 302,708 | 899,678 | 915,432 | - | - | 7,500 | 12,760 | 1,238,400 |
| Double Mountain Fork | 1,348,860 | 398,042 | 378,582 | 941,958 | 961,418 | - | - | 8,860 | 16,260 | 1,365,120 |
| Brazos above Possum Kingdom | 1,574,680 | 356,730 | 336,224 | 1,173,270 | 1,193,776 | 32,300 | 32,300 | 12,380 | 43,240 | 1,617,920 |
| California Creek | 653,600 | 311,542 | 296,170 | 328,218 | 343,590 | - | - | 13,840 | 27,360 | 680,960 |
| Elm Creek | 299,200 | 117,107 | 111,413 | 176,243 | 181,937 | - | - | 5,850 | 13,760 | 312,960 |
| Hubbard Creek | 776,400 | 173,649 | 160,681 | 547,551 | 560,519 | 47,500 | 47,500 | 7,700 | 38,960 | 815,360 |
| Clear Fork | 1,775,900 | 633,888 | 601,534 | 1,093,412 | 1,125,766 | 16,800 | 16,800 | 31,800 | 83,300 | 1,859,200 |
| Possum Kingdom | 642,530 | 139,417 | 128,746 | 395,323 | 405,994 | 99,660 | 99,660 | 8,130 | 51,870 | 694,400 |
| Possum Kingdom to Whitney | 1,298,880 | 286,941 | 257,210 | 791,769 | 821,500 | 192,540 | 192,540 | 27,630 | 88,640 | 1,387,520 |
| Palo Pinto | 387,270 | 86,246 | 78,412 | 226,554 | 234,388 | 69,500 | 69,500 | 4,970 | 14,650 | 401,920 |
| Paluxy Creek | 270,640 | 46,460 | 41,580 | 116,690 | 121,570 | 102,390 | 102,390 | 5,100 | 5,840 | 276,480 |
| Nolands River | 207,550 | 74,907 | 69,369 | 104,593 | 110,131 | 22,410 | 22,410 | 5,640 | 3,650 | 211,200 |
| Aquilla Creek | 259,810 | 148,086 | 132,211 | 88,244 | 104,119 | 17,220 | 17,220 | 6,260 | 7,070 | 266,880 |
| Bosque River | 961,406 | 396,234 | 347,838 | 404,114 | 452,510 | 145,542 | 145,542 | 15,516 | 111,234 | 1,072,640 |
| Whitney to Waco | 175,850 | 57,926 | 53,350 | 90,584 | 95,160 | 22,660 | 22,660 | 4,680 | 3,350 | 179,200 |
| Waco to Little River | 927,640 | 643,484 | 581,466 | 228,336 | 290,354 | 30,250 | 30,250 | 25,570 | 29,160 | 956,800 |
| Little River | 4,506,007 | 1,881,755 | 1,669,819 | 1,944,710 | 2,156,646 | 679,542 | 679,542 | - | 322,993 | 4,829,000 |
| Little Brazos | 411,380 | 175,149 | 158,741 | 185,721 | 202,129 | 42,420 | 42,420 | 8,090 | 9,740 | 421,120 |
| Navasota above Dam | 1,080,804 | 449,198 | 400,608 | 482,517 | 531,107 | 127,987 | 127,987 | 21.102 | 59,676 | 1,140,480 |
| Navasota below Dam | 247,130 | 68,250 | 60,786 | 125,860 | 133,324 | 49,160 | 49,160 | 3,860 | 5,670 | 252,800 |
| Yegua above Dam | 608,932 | 148,426 | 132,180 | 365,386 | 381,632 | 81,700 | 81,700 | 13,420 | 38,748 | 647,680 |
| Yegua below Dam | 198,460 | 43,214 | 38,495 | 110,156 | 114,875 | 41,200 | 41,200 | 3,890 | 5,700 | 204,160 |
| Mill Creek | 245,560 | 77,558 | 71,048 | 147,502 | 154,012 | 14,970 | 14,970 | 5,530 | 9,160 | 254,720 |
| Little River to Irrigation | 1,010,240 | 353,557 | 335,702 | 565,443 | 583,298 | 67,880 | 67,880 | 23,360 | 35,520 | 1,045,760 |
| Irrigation to Mouth | 388,630 | 167,903 | 166,224 | 211,577 | 213,256 | - | - | 9,150 | 11,370 | 400,000 |
| Total Brazos | 25,812,979 | 11,204,316 | 9,381,733 | 12,368,114 | 14,190,697 | 1,903,631 | 1,903,631 | 336,918 | 1,175,381 | 26,988,360 |

Error -- Non-Contributing Area, Cultivated, Present, Should be 3,447,850 rather than 3,477,850.

along the terrace channel reduces the load of sediment which it can carry. Installation costs per mile are as follows:

| Little River | Bosque River | Remainder of Brazos River | Brazos River Watershed |
|---|---|---|---|
| $134.05 | $128.77 | $132.96 | $133.11 |

Annual maintenance costs are estimated at 10 percent of installation.

## Field Diversions

Field diversions will be constructed to intercept and route runoff to selected points to protect severely eroded areas, valuable cropland and local high damage areas. In some cases field diversions will be used as the top terrace in a terrace system.

Costs per mile are estimated as follows:

| Little River | Bosque River | Remainder of Brazos River | Brazos River Watershed |
|---|---|---|---|
| $242.84 | $196.37 | $319.34 | $301.33 |

Annual maintenance costs are estimated as 3 percent of installation.

## Cover Crops

The use of annual legumes or closely-seeded crops to protect the surface of the soil, during seasons when clean cultivated crops leave the surface bare of vegetation, decreases runoff and soil loss and increases the rate of water penetration into the soil. The cost of installation for this practice is estimated at $3.75 per acre which includes seed and planting costs.

## Other Cropland Conservation Measures

Additional farm practices are necessary on cropland areas to retard runoff and protect the soil from erosion. All crops on fields not protected by terraces will be planted and cultivated on the contour to reduce runoff and erosion. Crop residue management and conservation crop rotations will be practiced on nearly all cultivated land to reduce runoff and erosion, to improve the physical condition of the soil, and to increase soil fertility and water-holding capacity. No costs were considered applicable, as these measures become a part of the farming system without increasing the farm operating cost. ?

Once being installed on [illegible] adequate to meet the needs of the farm.

Farm and Group Waterways

Natural and constructed waterways, including terrace outlets, will be stabilized to reduce sediment yields and land destruction resulting from uncontrolled runoff. These waterways will be shaped where necessary and vegetative cover established by seeding or sodding of adapted grasses.

The estimated costs per mile are as follows:

| Little River | Bosque River | Remainder of Brazos River | Brazos River Watershed |
|---|---|---|---|
| $159.61 | $228.00 | $150.89 | $152.90 |

Annual maintenance is estimated as 5 percent of the shaping and sodding costs.

Gully Stabilization

Approximately 2,378 miles of gullies (976 in the Little River, 361 miles in the Bosque and 1,041 miles in the remainder of the Brazos River Watershed) will be stabilized by the use of applicable measures such as diversions, bank sloping, seeding and sodding, fertilization and mulching. Measures for the large gullies include drop structures, small earthfill dams, drop inlets and such other stabilization devices as are necessary.

The estimated costs per mile are as follows:

| Little River | Bosque River | Remainder of Brazos River | Brazos River Watershed |
|---|---|---|---|
| $966.32 | $884.20 | $1,468.41 | $1,201.32 |

Annual maintenance costs are estimated as 3 percent of installation.

Establishment of New Grasslands

Idle land or cropland subject to severe erosion will be seeded to native grass or grass-legume mixtures to prevent excessive erosion and runoff. The capability of the land will be used as a guide in determining the utilization and establishing the type of grass cover needed. The measures needed to establish grass cover are preparation and planting, fertilization, and fencing to protect the seeded area.

Costs per acre of establishment are as follows:

| Little River | Bosque River | Remainder of Brazos River | Brazos River Watershed |
|---|---|---|---|
| $33.15 | $38.07 | $21.15 | $28.95 |

Annual maintenance costs are estimated to be 5 percent of fence construction or $0.70 per acre in the Little River, $0.96 per acre in the Bosque River, and $0.25 per acre in the remainder of the Brazos River.

Improvement and Management of Existing Grasslands

This group of measures will be applied individually or in combination to the present grassland area for the purpose of increasing the protective cover. The increase in amount of litter and in root growth will decrease runoff rates. Grazing management, including deferred and rotation grazing, will be practiced on all existing grasslands to improve the distribution and density of desirable grasses.

Seeding of grasslands which have an inadequate protective cover of perennial grasses will be necessary in many areas. Areas now grazed but covered with brush or light woods will be cleared and reseeded, where necessary, to promote the growth of desirable grasses.

The estimated costs per acre of improvement are as follows:

| Little River | Bosque River | Remainder of Brazos River | Brazos River Watershed |
|---|---|---|---|
| $11.53 | $14.14 | $4.41 | $5.01 |

No maintenance costs were estimated.

Sufficient seed gathering, cleaning and planting equipment is needed to facilitate seeding the pasture areas and to enable the landowners to develop their own seed gathering and cleaning program in order to attain the recommended accelerated rate of application of vegetative measures. The cost of the equipment is a Federal cost and operation and maintenance including replacement during the period of installation is a private cost.

The cost is estimated as follows:

| | Cost of Equipment | 15-year period of Operation & Maintenance |
|---|---|---|
| Little River | $ 62,700 | $ 420,000 |
| Bosque River | $ 16,000 | $ 100,000 |
| Remainder of Brazos River | $186,000 | $1,260,000 |
| Brazos River Watershed | $264,700 | $1,780,000 |

Maintenance and replacement costs will approximate 30 percent per year on this type of machinery.

Woodland Fire Protection

Approximately 500,000 acres of private woodland in the Forested Coastal Plain portion of the watershed will be protected from fires, the goal being to limit the annual burn to 1 percent or less of the area under protection. This woodland consists of low-grade scrub hardwoods of little commercial value. None of it is under organized protection and it is unlikely that any of it will receive such protection under going programs during the next 15 years.

A low-cost extensive type of protection is proposed which will utilize local voluntary services and cooperative effort in preventing and suppressing forest fires. Public assistance will be provided local groups in organizing for protection, in supplying fire control equipment where needed, and in carrying on educational work to prevent fires and enlist public support and participation.

The estimated cost of providing adequate fire protection is 2 cents per acre annually during the 15-year period of installation and annually thereafter. To enable effective accomplishment of the measure, the Federal Government will bear up to 75 percent of the cost, the remainder to be borne by the State with such local or private contributions as may be available. A substantial Federal contribution is required because timber values are lacking and the area is of low priority for protection under going programs.

Technical Services

Technical services will be made available to owners, operators and administrators of farm and ranch lands for planning and applying the necessary land use adjustments, for planning and applying land treatment practices and measures, and for integrating this work with

other measures included in the recommended program. The cost of furnishing these services is a Federal cost and approximates $2.00 per acre affected during the 15-year period of installation as follows:

| | |
|---|---|
| Little River | $ 3,675,000 |
| Bosque River | $ 825,000 |
| Remainder of Brazos | $ 9,694,605 |
| Brazos River Watershed | $14,194,605 |

The estimated costs of independent measures include engineering and design costs, and these are not included in the estimated cost of technical services.

Educational Assistance

Land owners and operators will be furnished educational assistance. They will be supplied information as to the manner in which services and assistance are made available through the various governmental agencies, and how they, by their own efforts can contribute most economically to the success of the program. Intensified educational efforts will be directed to familiarizing farmers with

the recommended practices and measures, how to install and apply measures not requiring technical assistance and how to maintain such measures. The cost of educational assistance on a subwatershed basis has been estimated by the Agricultural Extension Service.

The cost of educational assistance per acre treated or square mile of watershed area is approximately as follows:

| | Per Acre | Per Square Mile |
|---|---|---|
| Little River | $0.17 | $42.35 |
| Bosque River | $0.17 | $42.06 |
| Remainder of Brazos River | $0.19 | $31.39 |
| Brazos River Watershed | $0.18 | $34.15 |

Administrative Cost of Direct Aids

The recommended program includes the payment of direct aids to individual farmers and ranchers by the Federal Government to defray portions of the cost of certain measures. These Federal payments are based upon present rates of payment per unit. Payment on the units to be treated under the recommended program would therefore occur during the 15-year period of installation and would not duplicate payments made under the going programs. The cost of administering these direct aids is 5 percent of the payment. The Federal cost of administering direct aids per acre treated is as follows:

| | |
|---|---|
| Little River | $0.10 |
| Bosque River | $0.08 |
| Remainder of Brazos River | $0.16 |
| Brazos River Watershed | $0.14 |

## INDEPENDENT MEASURES

### Floodwater Retarding Structures

Surveys of possible floodwater retarding structure sites were made in 20 sample tributaries within the Brazos River Watershed. Consideration was given to the location and evaluation of these sites on the basis of the additional protection from overflows which they would afford in addition to reductions in runoff resulting from land treatment measures applied to the areas above. It was determined that a system of structures, located on small upland branches, is feasible and is needed to reduce the frequency and severity of flooding on the cultivated, alluvial areas below each structure (figure 29). It is estimated that approximately 555 upstream floodwater retarding structures are needed for the entire watershed, of which 287 are in the Little River Watershed and 61 are in the Bosque River Watershed. The approximate number and average size of these structures are shown by subwatersheds in table 26.

The typical structure will have about 10 square miles of drainage area and will be located directly above cultivated alluvial lands which are frequently overflowed. The structures are located and designed to reduce usual peak flows to discharges smaller than channel capacity during the majority of flood-producing storm periods and will achieve substantial reductions in flood damage.

The average structure will be rolled-earth fill and provided with a drop inlet for automatic draw-down to the top of the conservation storage pool within 144 hours. Side spillways will be provided for discharges which may occur in excess of the capacity of the draw-down tube and reservoir storage. As required for safety and economy and determined by the characteristics of each site, either sod, concrete or a combination of both will be used in the spillway construction. Investigations indicate that concrete side spillways will be needed on about 30 percent of the structures.

The volumes of retarding storage in each structure will be sufficient to detain about 3 inches of flood runoff from the drainage area. This amount will be in addition to the amount discharged through the draw-down tube during the period of watershed runoff. In addition, a conservation pool of not more than 250 acre-feet in capacity may be provided for a sediment catch basin. The amount will be varied in accordance with local requirements and the condition of the drainage area.

In the Grand Prairie, Reddish Prairie, Rolling Red Plains and Edwards Plateau conservation problem areas it is estimated that 25 percent or more of the sites required in connection with floodwater


Figure 29

AREAS IN WHICH UPSTREAM FLOODWATER RETARDING STRUCTURES WERE CONSIDERED

BRAZOS RIVER WATERSHED - TEXAS

U S DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

H H BENNETT-CHIEF

REGION 4 CONSERVATOR-LOUIS P MERRILL

4-R-7245-28

retarding structures will be furnished by the landowners without cost. The remaining sites will be provided by local interests unless it is not feasible for them to do so. When it is not feasible for local interests to furnish the site required in connection with an individual structure, it will be provided at Federal expense. Wherever possible, the title to these sites should rest with the non-Federal interests responsible for operation and maintenance.

The annual maintenance cost during and after the period of installation is estimated to be $200 per structure, and is considered a private cost.

Floodway and Channel Improvement

Channel improvement is economically feasible in several tributary streams. Survey investigations of floodway and channel improvement were limited to situations where channels of inadequate size would cause frequent floods even though land treatment measures and detention storage were applied. In the subwatersheds investigated only 81 miles of channel rectification or improvement are recommended; of this 7 miles are recommended in the Little River Survey Report. The channels proposed for improvement fall into two general classes:

1. Small tributary streams which cross the main Brazos River flood plain to reach the Brazos River. These streams have restricted channels and their overflow causes flooding of a portion of the Brazos River flood plain during local storms which do not affect the main Brazos River. Benefits are in reduced crop damage on the Brazos River bottomland directly affected by these streams.

2. Larger tributary streams with broad flood plains which now have sedimented or clogged channels. The bottomlands of these streams are still in cultivation or have recently been cultivated but have experienced or are experiencing a forced change to pasture use or to less valuable crops because of too frequent overflow damage. The benefits evaluated are from reductions in crop damage and the increased income to be derived from the more intensive use of the land.

It is recommended that the cost of channel excavation be borne by the Federal Government and that the cost of spoil bank disposal, easements and right-of-way, and maintenance be borne by the landowners (table 44).

Table 43. Costs of Floodwater Retarding Structures by Subwatersheds. (1949 Prices)

Brazos River Watershed

| Subwatershed | Number of Structures | Federal Costs | | | | Non-Federal Costs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Public | Private | | | |
| | | Structure | Engineering | Contingency 1/ | Total | Site | Site | Maintenance 2/ | Total | Grand Total |
| | | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Possum Kingdom to Whitney | 9 | 795,983 | 79,598 | 198,995 | 1,074,576 | 109,386 | 29,849 | 28,177 | 167,412 | 1,241,988 |
| Paluxy | 15 | 921,503 | 92,150 | 230,375 | 1,244,028 | 97,897 | 32,633 | 35,720 | 166,250 | 1,410,278 |
| Aquilla | 30 | 1,168,619 | 116,862 | 292,155 | 1,577,636 | 636,900 | - | 63,800 | 700,700 | 2,278,336 |
| Bosque | 61 | 3,401,014 | 340,102 | 850,255 | 4,591,371 | 648,750 | 115,000 | 114,000 | 877,750 | 5,469,121 |
| Whitney to Waco | 3 | 84,705 | 8,471 | 21,178 | 114,354 | 36,900 | - | 7,200 | 44,100 | 158,454 |
| Waco to Little River | 82 | 3,039,755 | 303,976 | 759,940 | 4,103,671 | 2,255,330 | - | 158,400 | 2,413,730 | 6,517,401 |
| Little River | 287 | 11,552,254 | 1,155,225 | 2,888,063 | 15,595,542 | 4,155,525 | 662,400 | 401,800 | 5,219,725 | 20,815,267 |
| Little Brazos | 29 | 1,285,772 | 128,577 | 321,443 | 1,735,792 | 427,373 | - | 69,400 | 496,773 | 2,232,565 |
| Navasota above Dam | 27 | 762,345 | 76,235 | 190,588 | 1,029,168 | 332,100 | - | 65,400 | 397,500 | 1,426,668 |
| Yegua above Dam | 12 | 668,402 | 66,840 | 167,100 | 902,342 | 184,000 | - | 30,000 | 214,000 | 1,116,342 |
| Total | 555 | 23,680,352 | 2,368,036 | 5,920,092 | 31,968,480 | 8,884,161 | 839,882 | 973,897 | 10,697,740 | 42,666,420 |

1/ Includes the estimated cost of maintenance and repairs which may be required from the time a structure is completed to the time of its transfer in good condition to the local operating and maintaining agency.

2/ Maintenance during the installation period at $200.00 per year per completed structure.

Table 44. Costs of Floodway and Channel Improvements by Subwatersheds (1949 Prices)

Brazos River Watershed

| Subwatershed | Miles | Federal Cost | | | Private Cost 3/ | Total Cost |
|---|---|---|---|---|---|---|
| | | Construction 1/ | Bridges 2/ | Total | | |
| | | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Little River | 7.00 | 466,900 | - | 466,900 | 136,700 | 603,600 |
| Waco to Little River | 40.35 | 502,855 | 108,049 | 610,904 | 509,421 | 1,120,325 |
| Navasota above Dam | 33.60 | 541,913 | 42,120 | 584,033 | 512,967 | 1,097,000 |
| Total | 80.95 | 1,511,668 | 150,169 | 1,661,837 | 1,159,088 | 2,820,925 |

1/ Includes excavation, clearing, watergates and 30 percent for engineering and contingency. Contingency includes the estimated cost of maintenance and repairs which may be required from the time the installation is completed to the time of its transfer in good condition to the local operating and maintaining agency.

2/ Includes 30% for engineering and contingency.

3/ Includes rights-of-way, fencing and spoil bank disposal.

Hydrologic Studies to Facilitate Program Installation

It is recommended that measuring devices be installed on selected segments of subwatersheds to obtain quantitative information on rainfall and runoff, and the sediment loads of streams, to facilitate installation of the recommended program. The measurements should include:

(a) Measurement of the total quantity and quality of waterflow, base flow, bank storage, groundwater recharge, rate of return of groundwater to the stream and sediment loads in small streams.

(b) Measurement of precipitation and determination of rainfall-runoff relationship.

(c) Determination of the flood hydrographs in small drainage areas (5,10, 40, 50, to 100 square miles) to assist in design of remedial measures and flood routing.

At present the only source of data for watersheds larger than fractional acreages concerning the effects of land treatment practices on rainfall-runoff relationships and sediment loads of streams is the Waco Hydrologic Laboratory. This station is equipped to furnish such data for Blackland Prairie conditions, for drainage areas up to approximately five square miles.

River gages for stream flow measurements are being operated only on large streams and our survey hydrologic evaluations have been dependent upon these river gages as check points. Determinations of the rainfall-runoff relationships in tributary watersheds have been based on high water marks, channel and flood plain surveys, and computed hydrograph relationships; adequate records not being available for checking these computations. Measurements of rainfall and runoff in tributary watersheds need to be made to provide design information to facilitate the application of the recommended program.

A review of present information was made in cooperation with the U. S. Geological Survey and a plan evolved for measuring the quantitative effects of the recommended program. The data obtained also would be useful in the design of adequate floodwater retarding and erosion prevention measures.

The recommendations of the subcommittee on Hydrologic Data of the Federal Inter-Agency River Basin Committee as to location of gages were given priority as these stations were considered desirable by several agencies and the records will be usable by the Corps of Engineers,

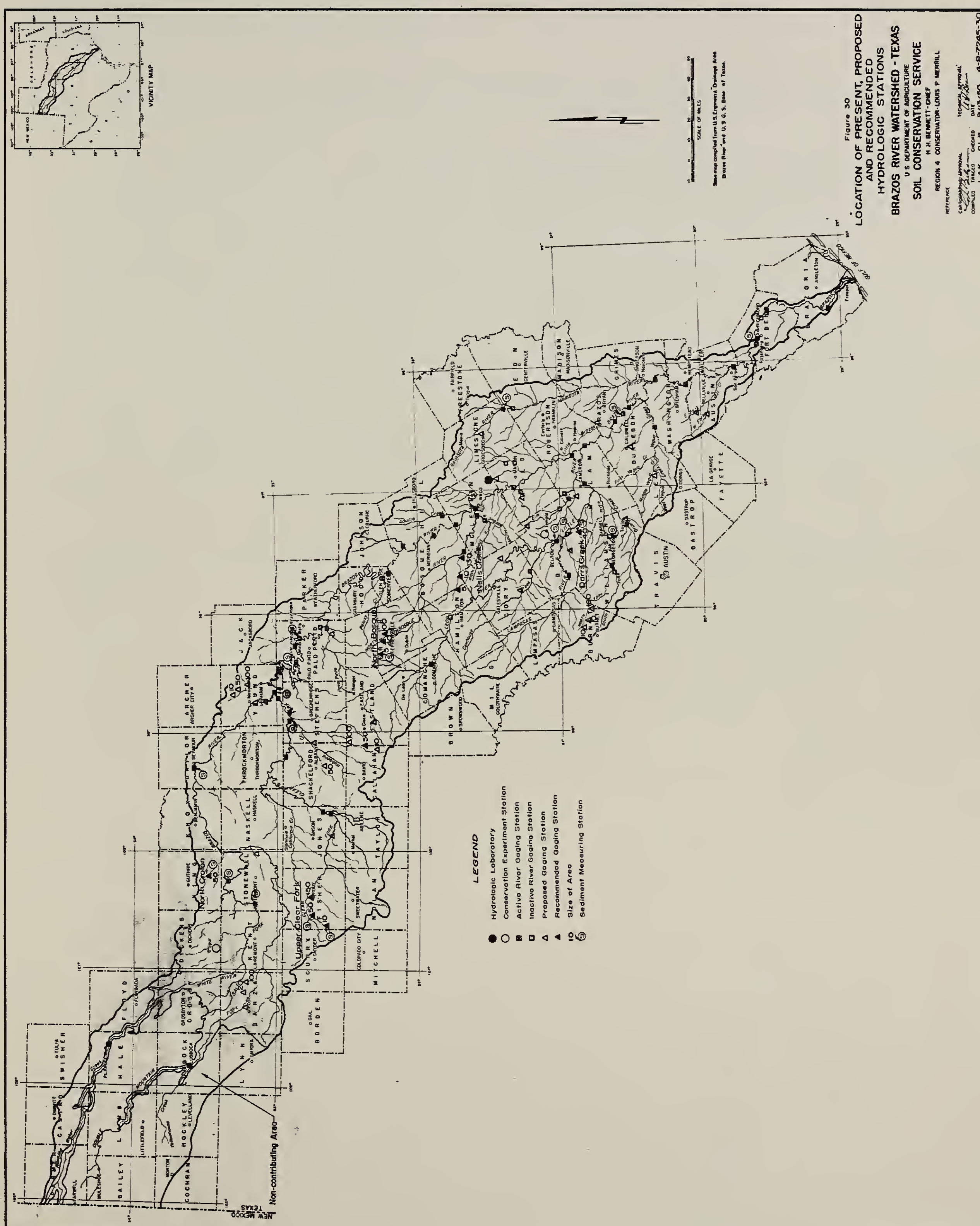
Figure 30
LOCATION OF PRESENT, PROPOSED
AND RECOMMENDED
HYDROLOGIC STATIONS
BRAZOS RIVER WATERSHED - TEXAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H H BENNETT-CHIEF
REGION 4 CONSERVATOR-LOUIS P MERRILL
REFERENCE
CARTOGRAPHIC APPROVAL
TECHNICAL APPROVAL
COMPILED TRACED LAK CHECKED GLB DATE 9/15/50 4-R-7245-30
F.J.B. APRIL 1949 Base 4-R-724
LEGEND
Hydrologic Laboratory
Conservation Experiment Station
Active River Gaging Station
Inactive River Gaging Station
Proposed Gaging Station
Recommended Gaging Station
Size of Area
Sediment Measuring Station
VICINITY MAP
Non-contributing Area
NEW MEXICO
TEXAS
North Croton
Upper Clear Fork
North Bosque
Cow Bayou
Green Creek
Deer Creek

Bureau of Public Roads, Bureau of Reclamation, Federal Power Commission, and many other Federal, State and local agencies. Final location of the areas to be measured should be determined only after adequate geological and land use surveys.

The active and inactive river gaging stations are listed in Appendix III (figures 8 and 11). These stations are also shown on figure 30.

It is recommended that five small watersheds be selected in each of these or similar drainage areas as follows: North Croton Creek, Upper Clear Fork (Verbena Creek), North Bosque River, Neils Creek, and Darrs Creek (table 45 and figure 30). A rather dense network of recording precipitation gages will be located on each small watershed to collect detailed rainfall information for correlation with runoff; water stage recorders will be placed on drainage areas of various sizes (table 45); observation wells, with either recording or non-recording measuring devices, will be placed in appropriate locations to evaluate groundwater recharge, bank storage and base or groundwater-flow after periods of rainfall. Sediment sampling stations will be maintained at a few gages to secure information regarding the sediment losses from small drainage areas.

Costs of installation and annual maintenance are shown in tables 46 and 47.

Table 45. Instrumentation of Recommended Sites for Measuring Precipitation, Stream Flow, Groundwater Recharge, and Sediment Loads.

Brazos River Watershed

| Conservation Problem Area, Approximate Location | Size of Drainage Area, Approximate (square miles) | Recording Streamflow Gages (number) | Recording Observation Wells and Gages 1/ (number) | Non-recording Observation 1/ Wells & Gages (number) | Recording Rain Gages 1/ (number) | Sediment Sampling Stations |
|---|---|---|---|---|---|---|
| Rolling Red Plain, North Croton Creek | 50 | 1 | 2 | 2 | 6 | 1 |
| Rolling Red Plain, Upper Clear Fork | 10 | 1 | - | - | - | 1 |
| Rolling Red Plain, Upper Clear Fork | 50 | 1 | - | - | - | 1 |
| Rolling Red Plain, Upper Clear Fork | 150 | 1 | 3 | 8 | 16 | - |
| Cross Timbers, North Bosque River | 5 | 1 | - | - | - | 1 |
| Cross Timbers, North Bosque River | 40 | 1 | - | - | - | - |
| Cross Timbers, North Bosque River | 100 | 1 | 4 | 8 | 16 | 1 |
| Grand Prairie, Neils Creek | 5 | 1 | - | - | - | - |
| Grand Prairie, Neils Creek | 10 | 1 | - | - | - | - |
| Grand Prairie, Neils Creek | 130 | 1 | 2 | 4 | 18 | - |
| Blackland Prairie, Darrs Creek | 40 | 1 | 2 | 4 | 10 | 1 |
| Total | - | 11 | 13 | 26 | 66 | 6 |

1/ Locations to be decided upon after survey of drainage area.

Table 46. Estimated Cost of Installation of Measuring Devices on Recommended Sites

Brazos River Watershed

| Approximate Location | Geologic and Location Surveys (dollars) | Waterflow Gages (dollars) | Observation Wells (dollars) | Rain Gages (dollars) | Total (dollars) |
|---|---|---|---|---|---|
| North Croton Creek | 500 | 3,000 | 1,600 | 1,020 | - |
| Upper Clear Fork | 500 | 9,000 | 3,400 | 2,720 | - |
| North Bosque River | 3,000 | 9,000 | 4,000 | 2,700 | - |
| Neils Creek | 500 | 9,000 | 2,000 | 3,060 | - |
| Darrs Creek | 500 | 3,000 | 2,000 | 1,700 | - |
| Total Cost of Installation | 5,000 | 33,000 | 13,000 | 11,200 | 62,200 |

Table 47. Estimated Annual Cost of Operation and Maintenance of Measuring Devices on Recommended Sites

Brazos River Watershed

| Approximate Location | Waterflow Gages | Recording Observation Wells | Non-Recording Observation Wells | Rain Gages | Sediment Sampling Station | Total All Stations |
|---|---|---|---|---|---|---|
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| North Croton Creek | 700 | 600 | 200 | 600 | 400 | - |
| Upper Clear Fork | 2,100 | 900 | 800 | 1,600 | 800 | - |
| North Bosque River | 2,100 | 1,200 | 800 | 1,600 | 800 | - |
| Neils Creek | 2,100 | 600 | 400 | 1,800 | - | - |
| Darrs Creek | 700 | 600 | 400 | 1,000 | 400 | - |
| Total Annual Maintenance | 7,700 | 3,900 | 2,600 | 6,600 | 2,400 | 23,200 |

Total Maintenance for 20 years - $464,000.

# APPENDIX VI
# PROGRAM APPRAISAL
# BRAZOS RIVER WATERSHED

The recommended program will reduce damage caused by floodwater and sediment, will increase the productive value of certain flood plain lands and will increase the income of land operators. The reductions in damages and increases in production and income are the benefits from the program. The purpose of this appendix is to set forth the monetary evaluations of the benefits accruing from the program and components thereof and to compare these benefits with the cost of the program or of the applicable component part.

Analyses of flood flows and related damages without and with the several component parts of the recommended program in effect determined the estimated annual damages under the various conditions. The difference between damages without and with a group of measures of the program installed determined the estimated annual benefit of the group. The benefits resulting from reduction of floodwater, sediment and indirect damages were divided into the benefits attributed to the going program and to the land treatment measures of the recommended program in proportion to the average annual costs of each.

## REDUCTION OF DAMAGE FROM FLOODWATER AND SEDIMENT

### Reduction in Floodwater Damage

Acres Damaged: About 1,015,000 acres of bottomland in the Brazos River Watershed are damaged by runoff waters. Each year, on an average, a total of about 1,029,000 acres are flooded, including replication of acreages flooded more than once during the year. The recommended program will reduce the average total acreage flooded each year to about 652,000 acres or a reduction of about 37 percent. The average depth of inundation on the flooded areas will be reduced by the recommended program.

Crops and Pasture Damage: Flood damage to crops and pasture at 1949 prices averages $10,303,906 annually under present conditions. 1/ It is expected that installation of the recommended program will result in an average annual benefit of $3,597,353 of which $902,773 will result from installation of land treatment measures, $2,534,060 from floodwater retarding structures and $160,520 from channel improvement. Reduction in damages to crops and pasture will be the largest of the flood control benefits, amounting to 72 percent of all benefits derived from reduction in damages caused by floodwater and sediment.

---

1/ In this evaluation it is assumed that the reservoirs in the Brazos River Watershed recommended by the Corps of Engineers will be constructed.

Flood Plain Scour Damage: Reduction in damage from flood plain scour will amount to $112,115 annually, approximately 3 percent of the total benefits from reduction in damages. The land treatment measures will account for $25,725 of this benefit, floodwater retarding structures $93,765, and channel improvement $5,625.

Other Agricultural Damage: It is estimated that the recommended program will reduce average annual damage to fences, livestock, farm buildings, trees, farm roads, stored crops, and similar items by $569,684, about 11 percent of the benefit from reduction of damage. A benefit of $204,505 results from installation of the land treatment measures, $342,710 from floodwater retarding structures, and $22,469 from channel improvement.

Non-Agricultural Damage: The average annual benefit from reduction of damage to highways, bridges, railroads, urban and other non-agricultural property will be $140,935 and will approximate 3 percent of all benefits from reduction of damage. The installation of land treatment measures will accomplish $55,790, and floodwater retarding structures $82,679, and channel improvement $2,466 of this benefit.

The benefits from reduction of direct floodwater damage are summarized for the Little River, the Bosque River and the remainder of the Brazos River Watershed below:

| | Benefit from Reduction of Damage to: | | | |
|---|---|---|---|---|
| | Crops and Pasture | Flood Plain Scour | Other Agricultural Property | Non-Agricultural Property |
| Little River | $2,435,805 | $104,144 | $180,700 | $ 50,125 |
| Bosque River | 113,805 | 2,713 | 27,385 | 3,365 |
| Remainder of Brazos River | 1,047,743 | 18,258 | 361,599 | 87,445 |
| Brazos River Watershed | $3,597,353 | $125,115 | $569,684 | $140,935 |

Reduction of Sedimentation Damage

Valley Sedimentation: The benefit from reduction in valley sedimentation is estimated to be $50,464 annually, of which $17,463 results from the land treatment measures, $31,107 from floodwater retarding structures and $1,894 from channel improvement. This benefit is about one percent of the total benefit from reduction of damages.

Reservoir Sedimentation: It is calculated that the average annual benefit through reduction of sedimentation of existing reservoirs and those recommended by the Corps of Engineers will be $99,987; $45,627 from the

land treatment measures, and $54,360 from floodwater retarding structures. The benefit to reservoirs will be about 2 percent of the benefits from reduction of damage.

Water Treatment: It is estimated that the annual benefit obtained from reduction of the cost of treating municipal water for removal of sediment will be $9,340. The land treatment measures will provide $3,844 of the benefit; the remainder, $5,496, will be due to floodwater retarding structures. This benefit will be less than 0.2 percent of the benefits from reduction of damage.

The benefits from reduction of sediment damage in the Little River, Bosque River and the remainder of the Brazos River Watershed are summarized below:

| | Benefit from Reduction of Sediment Damage | | |
|---|---|---|---|
| | Valley Sediment Deposition | Sedimentation of Reservoirs | Cost of Water Treatment |
| Little River | $28,758 | $52,946 | $ - |
| Bosque River | 1,232 | 10,420 | 5,810 |
| Remainder of Brazos River Watershed | 20,474 | 36,621 | 3,530 |
| Brazos River Watershed | $50,464 | $99,987 | $9,340 |

## Reduction of Indirect Damage

The benefit through reduction of losses to business, labor earnings and other phases of community life will approximate $372,487 annually, or 8 percent of all benefits from reduction of damages. The land treatment measures will contribute $87,918 of this benefit, floodwater retarding structures $260,425 and channel improvement $24,144.

This benefit includes $81,704 in the Little River, $13,473 in the Bosque River and $277,310 in the remainder of the Brazos River Watershed.

# INCREASED INCOME FROM THE RECOMMENDED PROGRAM

The recommended program will result not only in reduced damages from floodwater and sediment but also will increase the productivity of the watershed and the resulting incomes of its inhabitants.

## Intensification of Land Use in Flood Plains

The increase in net annual income from flood plain lands on which the agricultural use is expected to be intensified, after protection from flooding, is estimated at $724,342. Of this increase

$628,099 is due to the installation of floodwater retarding structures and $96,243 results from channel improvement.

This increased annual income will be $332,950 in the Little River, $63,065 in the Bosque River and $328,327 in the remainder of the Brazos River Watershed.

Indirect Benefits from Intensified Land Use: Increased production in the protected flood plains will contribute to the economic life of nearby communities through increased business, added income to workers in agricultural processing or servicing establishments and the like. This item has not been included in the benefit-cost evaluation.

Conservation Benefits

Reduction in Soil Loss: In determining the effects of the recommended program on soil losses, research data of experiment stations in Texas and Oklahoma were used. The sources used were:

USDA Technical Bulletin 859, "Investigations in Erosion Control and Reclamation of Eroded Land at the Blackland Conservation Experiment Station, Temple, Texas, 1931-1941".

USDA Technical Bulletin 916, "Investigations in Erosion Control and Reclamation of Sandy Clay Lands of Texas, Arkansas and Louisiana at the Conservation Experiment Station, Tyler, Texas, 1931-40".

USDA Technical Bulletin 837, "Investigations in Erosion Control and Reclamation of Eroded Land at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma, 1930-40".

"1941 Annual Report of the Tyler Experiment Station."

"1940 Annual Report of the Guthrie Experiment Station."

Texas Agricultural Experiment Station, Bulletin 587, "Water and Soil Conservation Experiments at Spur, Texas, 1940".

These data indicate that the installation of the recommended program will result in a reduction of 25,118,000 tons in the soil losses from watershed fields. The percentage reductions in soil losses due to the recommended program by subwatersheds is shown in table 48.

Farm Income: Changes in farm and ranch organization and increases in yields under the recommended program will result in an average annual benefit (through increases in farm receipts or decreases in farm expenses) of $25,345,497 annually. Operating costs (decreased farm receipts and

Table 48. Estimated Percentage of Reduction in Soil Losses Due to the Installation of the Recommended Program

Brazos River Watershed

| Subwatershed | Percent Reduction |
|---|---|
| Non-Contributing Area | 0 |
| White River | 0 |
| Salt Fork | 17 |
| Double Mountain Fork | 0 |
| Elm Creek | 12 |
| Hubbard Creek | 35 |
| Clear Fork | 15 |
| California Creek | 10 |
| Brazos above Possum Kingdom | 12 |
| Possum Kingdom | 28 |
| Palo Pinto Creek | 22 |
| Possum Kingdom to Whitney | 33 |
| Paluxy Creek | 33 |
| Whitney to Waco | 32 |
| Nolands River | 33 |
| Aquilla Creek | 34 |
| Bosque River | 22 |
| Waco to Little River | 36 |
| Little River | 28 |
| Little River to Irrigation | 25 |
| Little Brazos | 32 |
| Yegua above Dam | 23 |
| Yegua below Dam | 28 |
| Navasota above Dam | 33 |
| Navasota below Dam | 29 |
| Mill Creek | 29 |
| Irrigation to Mouth | 0 |
| Brazos River Watershed | 24 |

increased farm expenses: will total $7,544,507 annually. In addition, land owners and operators will be expected to expend the equivalent of $2,907,225 annually for the installation and maintenance of the land treatment measures. The average annual value of the cost of these measures to landowners and operators will be $10,451,732.

Effect of the Recommended Program on Farm and Ranch Operating Units: The following three adjustments will usually take place on all farm and ranch operating units: (1) Retirement of some land from cultivation to pasture, (2) installation of suitable mechanical structures and vegetative adjustments on cropland and grassland, and (3) adjustments in livestock numbers on grassland in accordance with long-time range grazing capabilities.

These adjustments and measures will involve no drastic organizational changes. Substantial crop and pasture yield increases will result from the program with a corresponding increase in livestock numbers in all conservation problem areas (page 236).

The benefit to be expected will exceed the cost of the program to land owners and operators in all conservation problem areas.

## NON-MONETARY BENEFITS

No values were placed upon intangible benefits such as enhancement of recreational values, improvement of public health, reduction in loss of life, and increased security from flood hazards. These several items, although they are significantly affected by control of floods and are highly important in the economy of the watershed, are not accurately measurable in monetary terms.

## COMPARISON OF BENEFIT AND COST

The average annual cost of the recommended program is $12,796,827. The installation costs were converted to an annual base using an interest rate of 2½ percent for public and 4 percent for private costs at 1949 prices. For details of the costs see tables 40 and 41, Appendix V.

The average annual benefits from the recommended program will be $31,035,204 at 1949 prices, of which $25,345,497 will be conservation benefits to land owners and operators. The costs and benefits are summarized by groups of measures and by subwatersheds in table 49. Damage estimates from which these estimates of benefits are derived, are summarized in table 39, Appendix IV.

Table 49. Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program Brazos River Watershed

| | Brazos River Watershed | | | |
|---|---|---|---|---|
| | Land Treatment Measures (dollars) | Floodwater Retarding Structures (dollars) | Channel Improvement (dollars) | Total (dollars) |
| Average Annual Costs | | | | |
| Federal | 880,873 | 873,064 | 41,548 | 1,795,485 |
| Non-Federal Public | 19,845 | 222,105 | - | 241,950 |
| Private | 10,451,732 | 185,713 | 121,947 | 10,759,392 |
| Total Average Annual Cost | 11,352,450 | 1,280,882 | 163,495 | 12,796,827 |
| Average Annual Benefits | | | | |
| Reduction in Floodwater Damage | | | | |
| Crops and Pasture | 902,773 | 2,534,060 | 160,520 | 3,597,353 |
| Flood Plain Scour | 25,725 | 93,765 | 5,625 | 125,115 |
| Other Agricultural | 204,505 | 342,710 | 22,469 | 569,684 |
| Non-Agricultural | 55,790 | 82,679 | 2,466 | 140,935 |
| Subtotal | 1,188,793 | 3,053,214 | 191,080 | 4,433,087 |
| Reduction in Sediment Damage | | | | |
| Valley Sediment Deposition | 17,463 | 31,107 | 1,894 | 50,464 |
| Reservoir Sedimentation | 45,627 | 54,360 | - | 99,987 |
| Cost of Water Treatment | 3,844 | 5,496 | - | 9,340 |
| Subtotal | 66,934 | 90,963 | 1,894 | 159,791 |
| Reduction in Indirect Damage | 87,918 | 260,425 | 24,144 | 372,487 |
| Increased Income from Flood Plain Lands | - | 628,099 | 96,243 | 724,342 |
| Conservation Benefit | 25,345,497 | - | - | 25,345,497 |
| Total Average Annual Benefit | 26,689,142 | 4,032,701 | 313,361 | 31,035,204 |
| Benefit: Cost Ratio | 2.35:1 | 3.15:1 | 1.92:1 | 2.43:1 |

1/ Does not include costs or benefits of going program.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program.
Brazos River Watershed

| | Salt Fork | Brazos to Poss.Kingd. | California Creek | Elm Creek | Hubbard Cr. |
|---|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 849 | 21,554 | 3,829 | 2,849 | 46,493 |
| Non-Federal Public | 32 | 519 | 186 | 119 | 774 |
| Private | 20,519 | 280,389 | 73,375 | 39,687 | 380,067 |
| Total Average Annual Cost | 21,400 | 302,462 | 77,390 | 42,655 | 427,334 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 922 | 2,179 | 737 | 328 | 1,832 |
| Flood Plain Scour | 137 | 212 | 43 | 28 | 368 |
| Other Agricultural | 89 | 4,868 | 584 | 609 | 2,102 |
| Non-Agricultural | 90 | 515 | 243 | 170 | 662 |
| Subtotal | 1,238 | 7,774 | 1,607 | 1,135 | 4,964 |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 81 | 56 | 35 | 8 | - |
| Reservoir Sedimentation | - | 5,936 | 1,409 | 509 | 1,854 |
| Cost of Water Treatment | - | 28 | 85 | 453 | 337 |
| Subtotal | 81 | 6,020 | 1,529 | 970 | 2,191 |
| Reduction in Indirect Damage | 215 | 447 | 249 | 39 | 236 |
| Increased Income from Flood Plain Lands | | | | | |
| Conservation Benefit | 65,560 | 373,246 | 195,209 | 96,564 | 455,331 |
| Total Average Annual Benefit | 67,094 | 387,487 | 198,594 | 98,708 | 462,722 |
| Benefit: Cost Ratio | 3.14:1 | 1.28:1 | 2.52:1 | 2.31:1 | 1.08:1 |

1/ Does not include costs or benefits of going program.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program.
Brazos River Watershed

| | Clear Fork | Possum Kingdom | Possum Kingdom to Whitney | | |
|---|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures | Floodwater Retarding Structures 2/ | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 26,183 | 31,897 | 104,600 | 29,345 | 133,945 |
| Non-Federal Public | 888 | 530 | 1,708 | 2,735 | 4,443 |
| Private | 336,077 | 273,827 | 500,352 | 4,744 | 505,096 |
| Total Average Annual Cost | 363,148 | 306,254 | 606,660 | 36,824 | 643,484 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 6,797 | 528 | 21,205 | 14,124 | 35,329 |
| Flood Plain Scour | 183 | 165 | 594 | 370 | 964 |
| Other Agricultural | 4,911 | 606 | 7,788 | 3,333 | 11,121 |
| Non-Agricultural | 1,289 | 152 | 687 | 587 | 1,274 |
| Subtotal | 13,180 | 1,451 | 30,274 | 18,414 | 48,688 |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 59 | 16 | 1,145 | 1,061 | 2,206 |
| Reservoir Sedimentation | 5,534 | 2,064 | 4,420 | 6,492 | 10,912 |
| Cost of Water Treatment | 534 | 96 | 307 | 504 | 811 |
| Subtotal | 6,127 | 2,176 | 5,872 | 8,057 | 13,929 |
| Reduction in Indirect Damage | 864 | 57 | 2,246 | 2,444 | 4,690 |
| Increased Income from Flood Plain Lands | - | - | - | 11,180 | 11,180 |
| Conservation Benefit | 634,203 | 434,910 | 1,482,241 | - | 1,482,241 |
| Total Average Annual Benefit | 654,374 | 438,594 | 1,520,633 | 40,095 | 1,560,728 |
| Benefit: Cost Ratio | 1.80:1 | 1.43:1 | 2.51:1 | 1.09:1 | 2.43:1 |

1/ Does not include costs or benefits of going program.

2/ Does not include area represented by Keechi Sample.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program.
Brazos River Watershed

| | Palo Pinto Creek | Paluxy Creek | | |
|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Floodwater Retarding Structures 3/ | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | |
| Federal | 26,006 | 15,953 | 33,975 | 49,928 |
| Non-Federal Public | 424 | 266 | 2,447 | 2,713 |
| Private | 172,298 | 78,477 | 5,765 | 84,242 |
| Total Average Annual Cost | 198,728 | 94,696 | 42,187 | 136,883 |
| Average Annual Benefits | | | | |
| Reduction in Floodwater Damage | | | | |
| Crops and Pasture | 1,319 | 16,205 | 21,518 | 37,723 |
| Flood Plain Scour | 91 | 439 | 457 | 896 |
| Other Agricultural | 1,247 | 4,816 | 5,927 | 10,743 |
| Non-Agricultural | 557 | 707 | 852 | 1,559 |
| Subtotal | 3,214 | 22,167 | 28,754 | 50,921 |
| Reduction in Sediment Damage | | | | |
| Valley Sediment Deposition | 247 | 1,555 | 813 | 2,368 |
| Reservoir Sedimentation | 1,373 | 666 | 785 | 1,451 |
| Cost of Water Treatment | 47 | - | - | - |
| Subtotal | 1,667 | 2,221 | 1,598 | 3,819 |
| Reduction in Indirect Damage | 141 | 2,202 | 3,581 | 5,783 |
| Increased Income from Flood Plain Lands | - | - | 14,008 | 14,008 |
| Conservation Benefit | 332,412 | 311,177 | - | 311,177 |
| Total Average Annual Benefit | 337,434 | 337,767 | 47,941 | 385,708 |
| Benefit: Cost Ratio | 1.70:1 | 3.57:1 | 1.14:1 | 2.82:1 |

1/ Does not include costs or benefits of going program.

3/ Does not include area represented by Palo Pinto Sample

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program. Brazos River Watershed

| | Nolands River | Aquilla Creek | | | Bosque River | | |
|---|---|---|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Floodwater Retarding Structures | Total | Land Treatment Measures | Floodwater Retarding Structures | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | | |
| Federal | 11,967 | 21,107 | 43,084 | 64,191 | 44,634 | 125,392 | 170,026 |
| Non-Federal Public | 214 | 376 | 15,923 | 16,299 | 881 | 16,219 | 17,100 |
| Private | 78,478 | 242,275 | 8,604 | 250,879 | 463,426 | 21,623 | 485,049 |
| Total Average Annual Cost | 90,659 | 263,758 | 67,611 | 331,369 | 508,941 | 163,234 | 672,175 |
| Average Annual Benefits | | | | | | | |
| Reduction in Floodwater Damage | | | | | | | |
| Crops and Pasture | 2,636 | 27,090 | 34,064 | 61,154 | 27,115 | 86,690 | 113,805 |
| Flood Plain Scour | - | 618 | 700 | 1,318 | 743 | 1,970 | 2,713 |
| Other Agricultural | 1,166 | 13,355 | 14,198 | 27,553 | 7,390 | 19,995 | 27,385 |
| Non-Agricultural | 173 | 2,842 | 3,363 | 6,205 | 1,053 | 2,312 | 3,365 |
| Subtotal | 3,975 | 43,905 | 52,325 | 96,230 | 36,301 | 110,967 | 147,268 |
| Reduction in Sediment Damage | | | | | | | |
| Valley Sediment Deposition | - | 773 | 904 | 1,677 | 280 | 952 | 1,232 |
| Reservoir Sedimentation | 753 | - | - | - | 2,797 | 7,623 | 10,420 |
| Cost of Water Treatment | - | - | - | - | 1,560 | 4,250 | 5,810 |
| Subtotal | 753 | 773 | 904 | 1,677 | 4,637 | 12,825 | 17,462 |
| Reduction in Indirect Damage | 243 | 4,689 | 5,673 | 10,362 | 2,949 | 10,524 | 13,473 |
| Increased Income from Flood Plain Lands | - | - | 41,374 | 41,374 | - | 63,065 | 63,065 |
| Conservation Benefit | 182,516 | 735,718 | - | 735,718 | 1,412,403 | - | 1,412,403 |
| Total Average Annual Benefit | 187,487 | 785,085 | 100,276 | 885,361 | 1,456,290 | 197,381 | 1,653,671 |
| Benefit: Cost Ratio | 2.07:1 | 2.98:1 | 1.48:1 | 2.67:1 | 2.86:1 | 1.21:1 | 2.46:1 |

1/ Does not include costs or benefits of going program.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program. Brazos River Watershed

| | Whitney to Waco | | | Waco to Little River | | | |
|---|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Total | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | | |
| Federal | 9,631 | 3,122 | 12,753 | 74,588 | 112,071 | 15,274 | 201,933 |
| Non-Federal Public | 177 | 923 | 1,100 | 1,373 | 56,383 | - | 57,756 |
| Private | 71,188 | 894 | 72,082 | 954,504 | 22,864 | 45,519 | 1,022,887 |
| Total Average Annual Cost | 80,996 | 4,939 | 85,935 | 1,030,465 | 191,318 | 60,793 | 1,282,576 |
| Average Annual Benefits | | | | | | | |
| Reduction in Floodwater Damage | | | | | | | |
| Crops and Pasture | 5,066 | 2,196 | 7,262 | 106,633 | 190,789 | 78,148 | 375,570 |
| Flood Plain Scour | 115 | 52 | 167 | 2,346 | 4,076 | 2,184 | 8,606 |
| Other Agricultural | 2,959 | 1,459 | 4,418 | 44,400 | 67,268 | 6,569 | 118,237 |
| Non-Agricultural | 449 | 379 | 828 | 9,033 | 16,242 | 633 | 25,908 |
| Subtotal | 8,589 | 4,086 | 12,675 | 162,412 | 278,375 | 87,534 | 528,321 |
| Reduction in Sediment Damage | | | | | | | |
| Valley Sediment Deposition | 71 | 75 | 146 | 3,335 | 3,904 | 676 | 7,915 |
| Reservoir Sedimentation | - | - | - | 526 | 907 | - | 1,433 |
| Cost of Water Treatment | - | - | - | 397 | 742 | - | 1,139 |
| Subtotal | 71 | 75 | 146 | 4,258 | 5,553 | 676 | 10,487 |
| Reduction in Indirect Damage | 516 | 321 | 837 | 13,989 | 28,122 | 16,206 | 58,317 |
| Increased Income from Flood Plain Lands | - | 3,359 | 3,359 | - | 94,995 | 82,588 | 177,583 |
| Conservation Benefit | 186,899 | - | 186,899 | 3,051,155 | - | - | 3,051,155 |
| Total Average Annual Benefit | 196,075 | 7,841 | 203,916 | 3,231,814 | 407,045 | 187,004 | 3,825,863 |
| Benefit: Cost Ratio | 2.42:1 | 1.59:1 | 2.37:1 | 3.14:1 | 2.13:1 | 3.08:1 | 2.98:1 |

1/ Does not include costs or benefits of going program.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/
(1949 Prices) of the Recommended Program.
Brazos River Watershed

| | Little River | | | | Little Brazos | | |
|---|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total | Land Treatment Measures | Floodwater Retarding Structures | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | | |
| Federal | 223,022 | 425,921 | 11,673 | 660,616 | 24,661 | 47,405 | 72,066 |
| Non-Federal Public | 4,344 | 103,888 | - | 108,232 | 778 | 10,684 | 11,462 |
| Private | 3,155,327 | 100,894 | 28,813 | 3,285,034 | 385,415 | 8,632 | 394,047 |
| Total Average Annual Cost | 3,382,693 | 630,703 | 40,486 | 4,053,882 | 410,854 | 66,721 | 477,575 |
| Average Annual Benefits | | | | | | | |
| Reduction in Floodwater Damage | | | | | | | |
| Crops and Pasture | 493,859 | 1,893,993 | 47,953 | 2,435,805 | 147,106 | 251,257 | 398,363 |
| Flood Plain Scour | 17,899 | 84,408 | 1,837 | 104,144 | 682 | 809 | 1,491 |
| Other Agricultural | 32,642 | 146,449 | 1,609 | 180,700 | 46,765 | 59,617 | 106,382 |
| Non-Agricultural | 16,731 | 33,398 | - | 50,129 | 14,989 | 19,914 | 34,903 |
| Subtotal | 561,131 | 2,158,248 | 51,399 | 2,770,778 | 209,542 | 331,597 | 541,139 |
| Reduction in Sediment Damage | | | | | | | |
| Valley Sediment Deposition | 7,288 | 20,823 | 647 | 28,758 | 760 | 903 | 1,663 |
| Reservoir Sedimentation | 16,753 | 36,193 | - | 52,946 | - | - | - |
| Cost of Water Treatment | - | - | - | - | - | - | - |
| Subtotal | 24,041 | 57,016 | 647 | 81,704 | 760 | 903 | 1,663 |
| Reduction in Indirect Damage | 30,197 | 154,750 | 2,877 | 187,824 | 23,822 | 49,512 | 73,334 |
| Increased Income from Flood Plain Lands | - | 332,950 | - | 332,950 | - | 21,945 | 21,945 |
| Conservation Benefit | 9,463,050 | - | - | 9,463,050 | 644,322 | - | 644,322 |
| Total Average Annual Benefit | 10,078,419 | 2,702,964 | 54,923 | 12,836,306 | 878,446 | 403,957 | 1,282,403 |
| Benefit: Cost Ratio | 2.98:1 | 4.29:1 | 1.36:1 | 3.17:1 | 2.14:1 | 6.05:1 | 2.69:1 |

1/ Does not include costs or benefits of going program.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program. Brazos River Watershed

| | Navasota River above Dam | | | | Navasota below Dam |
|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 52,284 | 28,106 | 14,601 | 94,991 | 12,005 |
| Non-Federal Public | 2,032 | 8,303 | - | 10,335 | 604 |
| Private | 1,043,624 | 8,069 | 47,615 | 1,099,308 | 234,067 |
| Total Average Annual Cost | 1,097,940 | 44,478 | 62,216 | 1,204,634 | 246,676 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 24,396 | 28,689 | 34,419 | 87,504 | - |
| Flood Plain Scour | 776 | 795 | 1,604 | 3,175 | - |
| Other Agricultural | 19,728 | 19,332 | 14,291 | 53,351 | - |
| Non-Agricultural | 3,795 | 4,252 | 1,833 | 9,880 | - |
| Subtotal | 48,695 | 53,068 | 52,147 | 153,910 | - |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 1,021 | 1,348 | 571 | 2,940 | - |
| Reservoir Sedimentation | 606 | 1,319 | - | 1,925 | - |
| Cost of Water Treatment | - | - | - | - | - |
| Subtotal | 1,627 | 2,667 | 571 | 4,865 | - |
| Reduction in Indirect Damage | 2,943 | 3,860 | 5,061 | 11,864 | - |
| Increased Income from Flood Plain Lands | - | 30,229 | 13,655 | 43,884 | - |
| Conservation Benefit | 1,965,004 | - | - | 1,965,004 | 382,014 |
| Total Average Annual Benefit | 2,018,269 | 89,824 | 71,434 | 2,179,527 | 382,014 |
| Benefit: Cost Ratio | 1.84:1 | 2.02:1 | 1.15:1 | 1.81:1 | 1.55:1 |

1/ Does not include costs or benefits of going program.

Table 49 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (1949 Prices) of the Recommended Program. Brazos River Watershed

| | Yegua Creek above Dam | | | Yegua Creek Below Dam | Mill Creek | Little R. to Irr. |
|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Total | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | |
| Federal | 54,599 | 24,643 | 79,242 | 15,910 | 17,982 | 38,270 |
| Non-Federal Public | 1,430 | 4,600 | 6,030 | 544 | 425 | 1,221 |
| Private | 668,676 | 3,624 | 672,300 | 210,512 | 212,911 | 576,261 |
| Total Average Annual Cost | 724,705 | 32,867 | 757,572 | 225,966 | 231,318 | 615,752 |
| Average Annual Benefits | | | | | | |
| Reduction in Floodwater Damage | | | | | | |
| Crops and Pasture | 7,307 | 10,740 | 18,047 | - | 4,619 | 4,894 |
| Flood Plain Scour | 86 | 128 | 214 | - | 97 | 103 |
| Other Agricultural | 2,469 | 5,132 | 7,601 | - | 2,919 | 3,092 |
| Non-Agricultural | 652 | 1,380 | 2,032 | - | 486 | 515 |
| Subtotal | 10,514 | 17,380 | 27,894 | - | 8,121 | 8,604 |
| Reduction in Sediment Damage | | | | | | |
| Valley Sediment Deposition | 210 | 324 | 534 | - | 254 | 269 |
| Reservoir Sedimentation | 427 | 1,041 | 1,468 | - | - | - |
| Cost of Water Treatment | - | - | - | - | - | - |
| Subtotal | 637 | 1,365 | 2,002 | - | 254 | 269 |
| Reduction in Indirect Damage | 1,155 | 1,638 | 2,793 | - | 350 | 369 |
| Increased Income from Flood Plain Lands | - | 14,994 | 14,994 | - | - | - |
| Conservation Benefit | 884,582 | - | 884,582 | 298,360 | 575,066 | 1,183,555 |
| Total Average Annual Benefit | 896,888 | 35,377 | 932,265 | 298,360 | 583,791 | 1,192,797 |
| Benefit: Cost Ratio | 1.24:1 | 1.08:1 | 1.23:1 | 1.31:1 | 2.52:1 | 1.94:1 |

1/ Does not include costs or benefits of going program.

Adjustment of Prices from 1949 to a Predicted Price Level

Estimates of damages and benefits in this report have been made on the basis of prices in 1949, the latest full calendar year for which prices were available. Since 1949 was a year in which prices were undergoing considerable adjustment, the 1949 benefits and costs herein have been factored for the purpose of comparing benefits and costs of the recommended program at a predicted normal or intermediate level. The factors were determined and used as follows:

(1) The standard used in this report for computing 1949 values of crops produced on farmland, livestock and livestock products is an index of 249 (1910-14 = 100). The index of the predicted level is 150 (1910-14 = 100). Therefore 150/249 or 0.6024 is the factor used to adjust 1949 prices to the predicted level. This factor was applied to all increased farm receipts in figuring conservation benefits and to decreased farm receipts in calculating operating costs to farmers.

(2) A standard prices-received-by-farmers index was developed for each sample area by weighting the 1949 index for each commodity by the quantity produced in each area. A corresponding predicted normal index was developed for each area and the factor derived by division of the normal index by that for 1949 was used in estimating the crop and pasture damage and the damage from flood plain scour. It was also used for measuring the benefits from more intensified use of flood plain lands. The average factor for the entire watershed is 0.6288.

(3) The standard used in this report for prices paid for items used by farmers in production is an index of 238 (1910-14 = 100) for 1949. The index of the predicted level is 155 (1910-14 = 100). Therefore 155/238 or 0.6513 is the factor used to adjust 1949 prices to the predicted level. This factor was applied to "other agricultural damages", to private costs of installation, operation and maintenance of the recommended program, and to damages by sedimentation of valley lands.

(4) The standard used in this report for construction costs is the Engineering News Record index for 1949 which is 477 (1913 = 100); the index of the predicted level is 325. Therefore 325/477 or 0.6813 is the factor used to adjust 1949 prices to the predicted level. This factor was applied to all benefits derived from a reduction in damage to nonagricultural property and in adjusting construction costs of the independent measures to normal prices.

(5) The standard used in this report for indirect damages is an index of 428 for wage rates in 1949. The index of the predicted level is 275; therefore 275/428 or 0.6425 is the factor used in adjusting indirect damages to predicted normal prices.

(6) It was believed that Federal salaries and travel costs would probably decline less than ordinary wage rates so a factor of 0.8212 was used to reduce the costs of technical services to the predicted normal level. This represents one-half of the predicted decline in wage rates.

## Comparison of Average Annual Benefit and Cost

Comparison of the average annual benefit with the average annual cost of the recommended program under normal prices provides the economic evaluation of the program. Table 50 presents the benefit and cost for each group of measures of the recommended program by sub-watersheds, after adjustment to normal prices by the factors described above.

The ratio between the benefit and cost of the land treatment measures is 2.20:1. The ratio for the floodwater retarding structures is 2.98:1. For channel improvement the ratio is 1.82:1. The ratio for the entire recommended program is 2.28:1.

## Comparison of the Effect of Discounting Delayed Benefits and Costs

There are certain types of benefits and costs resulting from the recommended program which will be delayed until treatment measures become fully effective. In this analysis, therefore, such benefits and costs were discounted to allow for this lag in effectiveness.

It was assumed that floodwater damage reductions, benefits from intensified use of flood plains and conservation benefits, resulting from land treatment measures, would, on an average, be delayed 5 years. A similar delay would be applicable to farm and ranch operating costs. It was also assumed that each of these benefits and costs would start at zero and build up uniformly to the maximum over the period of delay. They would then level off and remain constant thereafter.

Benefits from reductions in damage resulting from the installation of floodwater retarding structures and channel improvement will become fully effective immediately upon installation and, therefore, were not discounted.

Discounting deferred benefits and costs from land treatment measures would reduce their benefit-cost ratio (normal prices) from 2.20:1 to 2.15:1. The benefit-cost ratio for floodwater retarding structures would be reduced from 2.98:1 to 2.96:1 and for channel improvement from 1.82:1 to 1.79:1. The benefit-cost ratio for the recommended program would be reduced from 2.28:1 to 2.23:1.

Table 50. Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Brazos River Watershed | | | |
|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | |
| Federal | 633,057 | 594,822 | 28,307 | 1,256,186 |
| Non-Federal Public | 16,296 | 143,789 | - | 160,085 |
| Private | 6,707,618 | 121,127 | 79,329 | 6,908,074 |
| Total Average Annual Cost | 7,356,971 | 859,738 | 107,636 | 8,324,345 |
| Average Annual Benefits | | | | |
| Reduction in Floodwater Damage | | | | |
| Crops and Pasture | 569,542 | 1,592,868 | 99,610 | 2,262,020 |
| Flood Plain Scour | 16,254 | 60,536 | 3,485 | 80,275 |
| Other Agricultural | 133,245 | 223,200 | 14,635 | 371,080 |
| Non-Agricultural | 37,995 | 56,357 | 1,682 | 96,034 |
| Subtotal | 757,036 | 1,932,961 | 119,412 | 2,809,409 |
| Reduction in Sediment Damage | | | | |
| Valley Sediment Deposition | 11,347 | 20,258 | 1,209 | 32,814 |
| Reservoir Sedimentation | 31,457 | 37,025 | - | 68,482 |
| Cost of Water Treatment | 2,504 | 3,580 | - | 6,084 |
| Subtotal | 45,308 | 60,863 | 1,209 | 107,380 |
| Reduction in Indirect Damage | 56,319 | 168,089 | 15,426 | 239,834 |
| Increased Income from more Intensive Use of Flood Plain Land | - | 403,101 | 59,743 | 462,844 |
| Conservation Benefit | 15,348,986 | - | - | 15,348,986 |
| Total Average Annual Benefit | 16,207,649 | 2,565,014 | 195,790 | 18,968,453 |
| Benefit: Cost Ratio | 2.20:1 | 2.98:1 | 1.82:1 | 2.28:1 |

1/ Does not include costs or benefits of going program.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/
(Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Salt Fork | Brazos to Possum Kingdom | California Creek | Elm Creek | Hubbard Creek |
|---|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 579 | 14,900 | 2,623 | 1,945 | 34,015 |
| Non-Federal Public | 26 | 426 | 153 | 98 | 636 |
| Private | 13,364 | 176,429 | 47,790 | 25,843 | 238,475 |
| Total Average Annual Cost | 13,969 | 191,755 | 50,566 | 27,886 | 273,126 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 484 | 1,209 | 415 | 195 | 1,139 |
| Flood Plain Scour | 73 | 125 | 25 | 17 | 224 |
| Other Agricultural | 58 | 3,171 | 380 | 397 | 1,369 |
| Non-Agricultural | 61 | 350 | 167 | 116 | 451 |
| Subtotal | 676 | 4,855 | 987 | 725 | 3,183 |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 53 | 37 | 23 | 5 | - |
| Reservoir Sedimentation | - | 4,044 | 1,246 | 347 | 1,263 |
| Cost of Water Treatment | - | 18 | 55 | 295 | 220 |
| Subtotal | 53 | 4,099 | 1,324 | 647 | 1,483 |
| Reduction in Indirect Damage | 138 | 288 | 159 | 26 | 152 |
| Increased Income from More Intensive Use of Flood Plain Land | - | - | - | - | - |
| Conservation Benefit | 39,560 | 229,262 | 117,883 | 58,387 | 281,426 |
| Total Average Annual Benefit | 40,427 | 238,504 | 120,353 | 59,785 | 286,244 |
| Benefit: Cost Ratio | 2.89:1 | 1.24:1 | 2.38:1 | 2.14:1 | 1.05:1 |

1/ Does not include costs or benefits of going program.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Clear Fork | Possum Kingdom | Possum Kingdom to Whitney | | |
|---|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures | Floodwater Retarding Structures 2/ | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 17,973 | 23,222 | 76,812 | 19,995 | 96,807 |
| Non-Federal Public | 729 | 435 | 1,403 | 1,643 | 3,046 |
| Private | 215,678 | 172,633 | 322,046 | 3,074 | 325,120 |
| Total Average Annual Cost | 234,380 | 196,290 | 400,261 | 24,712 | 424,973 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 3,817 | 338 | 13,646 | 9,089 | 22,735 |
| Flood Plain Scour | 109 | 103 | 380 | 237 | 617 |
| Other Agricultural | 3,199 | 395 | 5,072 | 2,171 | 7,243 |
| Non-Agricultural | 877 | 104 | 469 | 404 | 873 |
| Subtotal | 8,002 | 940 | 19,567 | 11,901 | 31,468 |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 38 | 10 | 746 | 691 | 1,437 |
| Reservoir Sedimentation | 3,860 | 1,407 | 3,011 | 4,423 | 7,434 |
| Cost of Water Treatment | 348 | 63 | 200 | 328 | 528 |
| Subtotal | 4,246 | 1,480 | 3,957 | 5,442 | 9,399 |
| Reduction in Indirect Damage | 555 | 36 | 1,444 | 1,569 | 3,013 |
| Increased Income from More Intensive Use of Flood Plain Land | - | - | - | 7,192 | 7,192 |
| Conservation Benefit | 385,477 | 266,941 | 910,659 | - | 910,659 |
| Total Average Annual Benefit | 398,280 | 269,397 | 935,627 | 26,104 | 961,731 |
| Benefit: Cost Ratio | 1.70:1 | 1.37:1 | 2.34:1 | 1.06:1 | 2.26:1 |

1/ Does not include costs or benefits of going program.

2/ Does not include area represented by Keechi Sample.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Palo Pinto | Paluxy Creek | | | Noland's River |
|---|---|---|---|---|---|
| | Land Treatment Measures | Land Treatment Measures | Floodwater Retarding Structures 3/ | Total | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 19,027 | 11,725 | 23,147 | 34,872 | 8,729 |
| Non-Federal Public | 348 | 218 | 1,564 | 1,782 | 176 |
| Private | 109,143 | 51,083 | 3,737 | 54,820 | 50,991 |
| Total Average Annual Cost | 128,518 | 63,026 | 28,448 | 91,474 | 59,896 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 850 | 10,338 | 13,792 | 24,130 | 1,279 |
| Flood Plain Scour | 58 | 280 | 293 | 573 | - |
| Other Agricultural | 812 | 3,137 | 3,860 | 6,997 | 759 |
| Non-Agricultural | 379 | 481 | 580 | 1,061 | 118 |
| Subtotal | 2,099 | 14,236 | 18,525 | 32,761 | 2,156 |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 160 | 1,013 | 530 | 1,543 | - |
| Reservoir Sedimentation | 935 | 453 | 535 | 988 | 513 |
| Cost of Water Treatment | 30 | - | - | - | - |
| Subtotal | 1,125 | 1,466 | 1,065 | 2,531 | 513 |
| Reduction in Indirect Damage | 92 | 1,416 | 2,299 | 3,715 | 156 |
| Increased Income from More Intensive Use of Flood Plain Land | - | - | 8,898 | 8,898 | - |
| Conservation Benefit | 204,697 | 190,396 | - | 190,396 | 110,412 |
| Total Average Annual Benefit | 208,013 | 207,514 | 30,787 | 238,301 | 113,237 |
| Benefit: Cost Ratio | 1.62:1 | 3.29:1 | 1.08:1 | 2.61:1 | 1.89:1 |

1/ Does not include costs or benefits of going program.

3/ Does not include area represented by Palo Pinto Sample.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program. Brazos River Watershed

| | Aquilla Creek | | | Bosque River | | |
|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Total | Land Treatment Measures | Floodwater Retarding Structures | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | |
| Federal | 15,553 | 29,354 | 44,907 | 32,744 | 85,430 | 118,174 |
| Non-Federal Public | 309 | 9,832 | 10,141 | 723 | 9,942 | 10,665 |
| Private | 157,573 | 5,604 | 163,177 | 301,831 | 13,714 | 315,545 |
| Total Average Annual Cost | 173,435 | 44,790 | 218,225 | 335,298 | 109,086 | 444,384 |
| Average Annual Benefits | | | | | | |
| Reduction in Floodwater Damage | | | | | | |
| Crops and Pasture | 16,829 | 21,195 | 38,024 | 17,424 | 55,534 | 72,958 |
| Flood Plain Scour | 383 | 435 | 818 | 482 | 1,274 | 1,756 |
| Other Agricultural | 8,698 | 9,247 | 17,945 | 4,813 | 13,024 | 17,837 |
| Non-Agricultural | 1,938 | 2,291 | 4,229 | 717 | 1,575 | 2,292 |
| Subtotal | 27,848 | 33,168 | 61,016 | 23,436 | 71,407 | 94,843 |
| Reduction in Sediment Damage | | | | | | |
| Valley Sediment Deposition | 503 | 589 | 1,092 | 182 | 620 | 802 |
| Reservoir Sedimentation | - | - | - | 1,906 | 5,194 | 7,100 |
| Cost of Water Treatment | - | - | - | 1,016 | 2,768 | 3,784 |
| Subtotal | 503 | 589 | 1,092 | 3,104 | 8,582 | 11,686 |
| Reduction in Indirect Damage | 3,012 | 3,645 | 6,657 | 1,895 | 6,761 | 8,656 |
| Increased Income from More Intensive Use of Flood Plain Land | - | 25,671 | 25,671 | - | 39,951 | 39,951 |
| Conservation Benefit | 443,462 | - | 443,462 | 850,834 | - | 850,834 |
| Total Average Annual Benefit | 474,825 | 63,073 | 537,898 | 879,269 | 126,701 | 1,005,970 |
| Benefit: Cost Ratio | 2.74:1 | 1.41:1 | 2.46:1 | 2.62:1 | 1.16:1 | 2.26:1 |

1/ Does not include costs or benefits of going program.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/
(Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Whitney to Waco | | | Waco to Little River | | | |
|---|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Total | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | | |
| Federal | 7,030 | 2,128 | 9,158 | 54,844 | 76,354 | 10,406 | 141,604 |
| Non-Federal Public | 145 | 584 | 729 | 1,128 | 35,121 | - | 36,249 |
| Private | 46,261 | 582 | 46,843 | 619,838 | 14,891 | 29,647 | 664,376 |
| Total Average Annual Cost | 53,436 | 3,294 | 56,730 | 675,810 | 126,366 | 40,053 | 842,229 |
| Average Annual Benefits | | | | | | | |
| Reduction in Floodwater Damage | | | | | | | |
| Crops and Pasture | 3,208 | 1,345 | 4,553 | 66,419 | 119,346 | 49,046 | 234,811 |
| Flood Plain Scour | 73 | 32 | 105 | 1,458 | 2,550 | 1,372 | 5,380 |
| Other Agricultural | 1,927 | 950 | 2,877 | 28,917 | 43,812 | 4,279 | 77,008 |
| Non-Agricultural | 305 | 259 | 564 | 6,139 | 11,094 | 431 | 17,664 |
| Subtotal | 5,513 | 2,586 | 8,099 | 102,933 | 176,802 | 55,128 | 334,863 |
| Reduction in Sediment Damage | | | | | | | |
| Valley Sediment Deposition | 47 | 48 | 95 | 2,172 | 2,543 | 441 | 5,156 |
| Reservoir Sedimentation | - | - | - | 358 | 618 | - | 976 |
| Cost of Water Treatment | - | - | - | 259 | 484 | - | 743 |
| Subtotal | 47 | 48 | 95 | 2,789 | 3,645 | 441 | 6,875 |
| Reduction in Indirect Damage | 332 | 207 | 539 | 8,986 | 18,069 | 10,413 | 37,468 |
| Increased Income from More Intensive Use of Flood Plain Land | - | 2,057 | 2,057 | - | 59,026 | 51,354 | 110,380 |
| Conservation Benefit | 112,964 | - | 112,964 | 1,839,515 | - | - | 1,839,515 |
| Total Average Annual Benefit | 118,856 | 4,898 | 123,754 | 1,954,223 | 257,542 | 117,336 | 2,329,101 |
| Benefit: Cost Ratio | 2.22:1 | 1.49:1 | 2.18:1 | 2.89:1 | 2.04:1 | 2.93:1 | 2.77:1 |

1/ Does not include costs or benefits of going program.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Little River | | | | Little Brazos | | |
|---|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total | Land Treatment Measures | Floodwater Retarding Structures | Total |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | | |
| Federal | 148,448 | 290,180 | 7,953 | 446,581 | 22,581 | 32,296 | 54,877 |
| Non-Federal Public | 3,567 | 70,441 | - | 74,008 | 639 | 6,732 | 7,371 |
| Private | 2,055,066 | 66,288 | 18,670 | 2,140,024 | 243,054 | 5,622 | 248,676 |
| Total Average Annual Cost | 2,207,081 | 426,909 | 26,623 | 2,660,613 | 266,274 | 44,650 | 310,924 |
| Average Annual Benefits | | | | | | | |
| Reduction in Floodwater Damage | | | | | | | |
| Crops and Pasture | 313,780 | 1,189,823 | 29,345 | 1,532,948 | 92,728 | 158,518 | 251,246 |
| Flood Plain Scour | 11,385 | 54,640 | 1,124 | 67,149 | 425 | 507 | 932 |
| Other Agricultural | 21,311 | 95,375 | 1,048 | 117,734 | 30,458 | 38,828 | 69,286 |
| Non-Agricultural | 11,398 | 22,751 | - | 34,149 | 10,212 | 13,568 | 23,780 |
| Subtotal | 357,874 | 1,362,589 | 31,517 | 1,751,980 | 133,823 | 211,421 | 345,244 |
| Reduction in Sediment Damage | | | | | | | |
| Valley Sediment Deposition | 4,746 | 13,559 | 396 | 18,701 | 468 | 589 | 1,057 |
| Reservoir Sedimentation | 11,410 | 24,647 | - | 36,057 | - | - | - |
| Cost of Water Treatment | - | - | - | - | - | - | - |
| Subtotal | 16,156 | 38,206 | 396 | 54,758 | 468 | 589 | 1,057 |
| Reduction in Indirect Damage | 19,232 | 100,194 | 1,761 | 121,187 | 15,306 | 31,812 | 47,118 |
| Increased Income from More Intensive Use of Flood Plain Land | - | 219,046 | - | 219,046 | - | 13,519 | 13,519 |
| Conservation Benefit | 5,700,542 | - | - | 5,700,542 | 392,048 | - | 392,048 |
| Total Average Annual Benefit | 6,093,804 | 1,720,035 | 33,674 | 7,847,513 | 541,645 | 257,341 | 798,986 |
| Benefit: Cost Ratio | 2.76:1 | 4.03:1 | 1.26:1 | 2.95:1 | 2.03:1 | 5.76:1 | 2.57:1 |

1/ Does not include costs or benefits of going program.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Navasota River above Dam | | | | Navasota River below Dam |
|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Channel Improvement | Total | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 38,080 | 19,149 | 9,948 | 67,177 | 8,787 |
| Non-Federal Public | 1,669 | 5,100 | - | 6,769 | 496 |
| Private | 657,409 | 5,255 | 31,012 | 693,676 | 146,691 |
| Total Average Annual Cost | 697,158 | 29,504 | 40,960 | 767,622 | 155,974 |
| Average Annual Benefits | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crops and Pasture | 14,976 | 17,618 | 21,219 | 53,813 | - |
| Flood Plain Scour | 476 | 489 | 989 | 1,954 | - |
| Other Agricultural | 12,849 | 12,590 | 9,308 | 34,747 | - |
| Non-Agricultural | 2,587 | 2,895 | 1,251 | 6,733 | - |
| Subtotal | 30,888 | 33,592 | 32,767 | 97,247 | - |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 666 | 877 | 372 | 1,915 | - |
| Reservoir Sedimentation | 413 | 899 | - | 1,312 | - |
| Cost of Water Treatment | - | - | - | - | - |
| Subtotal | 1,079 | 1,776 | 372 | 3,227 | - |
| Reduction in Indirect Damage | 1,890 | 2,480 | 3,252 | 7,622 | - |
| Increased Income from More Intensive Use of Flood Plain Land | - | 18,515 | 8,389 | 26,904 | - |
| Conservation Benefit | 1,194,689 | - | - | 1,194,689 | 232,931 |
| Total Average Annual Benefit | 1,228,546 | 56,363 | 44,780 | 1,329,689 | 232,931 |
| Benefit: Cost Ratio | 1.76:1 | 1.91:1 | 1.09:1 | 1.73:1 | 1.49:1 |

1/ Does not inclue costs or benefits of going program.

Table 50 (Continued). Summary and Comparison of Average Annual Costs and Benefits 1/ (Normal Prices) of the Recommended Program.
Brazos River Watershed

| | Yegua Creek above Somerville | | | Yegua Cr. below Somerville | Mill Cr. | Little R. to Irr. |
|---|---|---|---|---|---|---|
| | Land Treatment Measures | Floodwater Retarding Structures | Total | Land Treatment Measures | Land Treatment Measures | Land Treatment Measures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | | |
| Federal | 40,564 | 16,789 | 57,353 | 11,846 | 13,229 | 27,801 |
| Non-Federal Public | 1,174 | 2,830 | 4,004 | 447 | 349 | 1,002 |
| Private | 420,737 | 2,360 | 423,097 | 132,399 | 137,076 | 366,208 |
| Total Average Annual Cost | 462,475 | 21,979 | 484,454 | 144,692 | 150,654 | 395,011 |
| Average Annual Benefits | | | | | | |
| Reduction in Floodwater Damage | | | | | | |
| Crops and Pasture | 4,496 | 6,608 | 11,104 | - | 2,900 | 3,072 |
| Flood Plain Scour | 52 | 79 | 131 | - | 61 | 65 |
| Other Agricultural | 1,608 | 3,343 | 4,951 | - | 1,901 | 2,014 |
| Non-Agricultural | 444 | 940 | 1,384 | - | 331 | 351 |
| Subtotal | 6,600 | 10,970 | 17,570 | - | 5,193 | 5,502 |
| Reduction in Sediment Damage | | | | | | |
| Valley Sediment Deposition | 137 | 212 | 349 | - | 166 | 175 |
| Reservoir Sedimentation | 291 | 709 | 1,000 | - | - | - |
| Cost of Water Treatment | - | - | - | - | - | - |
| Subtotal | 428 | 921 | 1,349 | - | 166 | 175 |
| Reduction in Indirect Damage | 742 | 1,053 | 1,795 | - | 225 | 237 |
| Increased Income from More Intensive Use of Flood Plain Land | - | 9,226 | 9,226 | - | - | - |
| Conservation Benefit | 540,052 | - | 540,052 | 182,023 | 347,293 | 717,533 |
| Total Average Annual Benefit | 547,822 | 22,170 | 569,992 | 182,023 | 352,877 | 723,447 |
| Benefit: Cost Ratio | 1.18:1 | 1.01:1 | 1.18:1 | 1.26:1 | 2.34:1 | 1.83:1 |

1/ Does not include costs or benefits of going program.

Evaluation of Independent Measures in Other Areas

Evaluations of the effects of floodwater retarding structures and of channel improvement were made in areas other than those listed in tables 49 and 50. In these additional areas the benefit-cost ratios were unfavorable as shown in table 51 and the independent measures are not recommended at this time. This finding, however, does not eliminate the possibility that detailed investigation prior to initiating the installation of land treatment measures on the tributary streams may show that floodwater retarding structures or channel improvement may be justified in parts of the subwatersheds where they are not recommended at this time.

## METHOD OF DETERMINING VALUE OF ANNUAL BENEFITS FROM REDUCTIONS IN FLOOD AND SEDIMENT DAMAGE

Floodwater and sediment damages were calculated under present conditions and under conditions which will prevail after the installation of the various groups of measures of the recommended program as described in Appendix IV, Flood Problems and Related Damages. The difference in annual damages at the time of initiation of a group of measures and those expected after its completion constitute a benefit of that group.

Benefits from reduction of crop and pasture, "other agricultural" and road and bridge damage were estimated from the combined effects of reduction in area inundated and depth of inundation. Use of the index of flooding caused reductions in area inundated to be the chief factor in estimating benefits from reduction of scour damage.

Benefits from reduction of sediment damage to reservoirs were calculated from estimates of the reductions in the quantity of sediment that would be deposited annually. For example, it was estimated that the deposition in Whitney Reservoir would be reduced from 2235 acre-feet to 1118 acre-feet annually. The benefit from continuation of the going program and the installation of the recommended program would be 1117 X $14.82 or $16,554.

Benefits from the reduction of valley sedimentation were estimated from reductions in the area inundated combined with reductions in the output of sediment as a result of the program. The following example shows the calculations for Mulberry Creek sample tributary.

Table 51 - Summary and Comparison of Average Annual Costs and Benefits (1949 Prices) of Measures in Areas in Which They Were Evaluated but Are Not Recommended at This Time

Brazos River Watershed

| | Salt Fork | Hubbard Creek | Clear Fork | Possum Kingdom | Possum Kingdom to Whitney 1/ |
|---|---|---|---|---|---|
| | Floodwater Retarding Structures | Floodwater Retarding Structures | Floodwater Retarding Structures | Floodwater Retarding Structures | Floodwater Retarding Structures |
| | (dollars) | (dollars) | (dollars) | (dollars) | (dollars) |
| Average Annual Costs | | | | | |
| Federal | 31,189 | 229,742 | 157,719 | 105,643 | 29,481 |
| Private | 3,383 | 25,740 | 23,771 | 14,344 | 5,186 |
| Total Average Annual Cost | 34,572 | 255,482 | 181,490 | 119,987 | 34,667 |
| Average Annual Benefit | | | | | |
| Reduction in Floodwater Damage | | | | | |
| Crop and Pasture | 7,699 | 5,935 | 9,968 | 1,790 | 575 |
| Flood Plain Scour | 1,077 | 1,284 | 369 | 571 | 177 |
| Other Agricultural | 654 | 7,135 | 12,066 | 1,467 | 451 |
| Non-agricultural | 615 | 1,649 | 2,696 | 309 | 120 |
| Subtotal | 10,045 | 16,003 | 25,099 | 4,137 | 1,323 |
| Reduction in Sediment Damage | | | | | |
| Valley Sediment Deposition | 459 | - | 161 | 38 | - |
| Reservoir Sedimentation | - | 3,091 | 13,176 | 3,394 | 414 |
| Cost of Water Treatment | - | 1,012 | 1,204 | 158 | 32 |
| Subtotal | 459 | 4,103 | 14,541 | 3,590 | 446 |
| Reduction in Indirect Damage | 1,950 | 707 | 1,796 | 191 | 62 |
| Increased Income from Intensified Use of Flood Plain Lands | 14,839 | 4,697 | 11,688 | 6,447 | 2,758 |
| Total Average Annual Benefit | 27,293 | 25,510 | 53,124 | 14,365 | 4,589 |
| Benefit:Cost Ratio | 0.79:1 | 0.10:1 | 0.29:1 | 0.12:1 | 0.13:1 |

1/ Only that portion of subwatershed represented by Keechi sample.
2/ Only that portion of subwatershed represented by Palo Pinto sample.

Table 51 - Summary and Comparison of Average Annual Costs and Benefits (1949 Prices) of Measures in Areas in Which They Were Evaluated but Are Not Recommended at This Time

Brazos River Watershed

| | Palo Pinto Creek | Paluxy Creek 2/ | Mill Creek | | Little River to Irrigation | |
|---|---|---|---|---|---|---|
| | Floodwater Retarding Structures (dollars) | Floodwater Retarding Structures (dollars) | Floodwater Retarding Structures (dollars) | Channel Improvement (dollars) | Floodwater Retarding Structures (dollars) | Channel Improvement (dollars) |
| Average Annual Costs | | | | | | |
| Federal | 160,438 | 34,244 | 41,446 | 4,635 | 44,969 | 7,726 |
| Private | 16,844 | 3,930 | 3,624 | 12,739 | 3,906 | 21,231 |
| Total Average Annual Cost | 177,282 | 38,174 | 45,070 | 17,374 | 48,875 | 28,957 |
| Average Annual Benefit | | | | | | |
| Reduction in Floodwater Damage | | | | | | |
| Crop and Pasture | 7,709 | 7,970 | 21,618 | 2,912 | 23,452 | 4,350 |
| Flood Plain Scour | 577 | 206 | 370 | 72 | 401 | 107 |
| Other Agricultural | 6,327 | 1,643 | 8,809 | 1,353 | 9,552 | 2,020 |
| Non-agricultural | 1,371 | 547 | 1,412 | 71 | 1,532 | 106 |
| Subtotal | 15,984 | 10,366 | 32,209 | 4,408 | 34,937 | 6,583 |
| Reduction in Sediment Damage | | | | | | |
| Valley Sediment Deposition | 577 | 610 | 584 | 22 | 634 | 33 |
| Reservoir Sedimentation | 2,214 | 255 | - | - | - | - |
| Cost of Water Treatment | 76 | - | - | - | - | - |
| Subtotal | 2,867 | 865 | 584 | 22 | 634 | 33 |
| Reduction in Indirect Damage | 888 | 1,365 | 1,992 | 309 | 2,172 | 462 |
| Increased Income from Intensified Use of Flood Plain Lands | 7,566 | 8,182 | - | 3,728 | - | 5,564 |
| Total Average Annual Benefit | 27,305 | 20,778 | 34,785 | 8,467 | 37,743 | 12,642 |
| Benefit:Cost Ratio | 0.15:1 | 0.54:1 | 0.77:1 | 0.49:1 | 0.77:1 | 0.44:1 |

1/ Only that portion of subwatershed represented by Keechi sample.
2/ Only that portion of subwatershed represented by Palo Pinto sample.

| | |
|---|---|
| Reduction in sediment output as a result of the recommended program | 50 percent |
| Reduction in overbank deposition due to decreased flooding as a result of the recommended program | 31.3 percent |
| Remaining overbank deposition after installation of the recommended program | 34.4 percent |
| Acreage damaged annually after installation of the program (5.3 x .344) | 1.82 |
| Annual increment of damage after installation | $91.00 |
| Annual decrease in damage during installation (265 - 91)/20 | $ 8.70 |
| Added capital investment in extra expense during period of installation (160.24184 x 8.70) | $1,394 |
| Capital investment required if program could be installed at once (23.51564 x $91) | $2,140 |
| Total capital investment caused by sediment damage if the recommended program is installed | $3,534 |
| Interest at 4 percent on investment (annual damage) | $ 141 |
| Annual damage without a program (Appendix IV, page 115) | $ 183 |
| Benefit from recommended program ($183-$141) | $ 42 |

The total monetary benefit was apportioned among the component parts of the recommended program in the same proportion as each component reduced the deposition of sediment. In those cases where installation of the recommended program reduced the rate of sediment deposition so greatly that the evaluation period with the recommended program would have exceeded 100 years, the annual "capital investment required if program could be installed at once" was capitalized at 4 percent.

Benefits from the reduction of crop and pasture damage, scour damage "other agricultural" and indirect damage derived from each group of measures were determined directly by analysis of sample tributaries. Other benefits from reduction of damage were evaluated on a subwatershed basis.

Table 52 shows the average annual benefit from reduction of damage to crops and pasture, from flood plain scour, "other agricultural", and indirect damage.

Table 52 - Summary of Benefits from Land Treatment Measures and Floodwater Retarding Structures, Mulberry Creek Sample Tributary Brazos River Watershed

| Source of Benefit | Average Annual Benefit 1/ | | |
|---|---|---|---|
| | From Land Treatment Measures | From Floodwater Retarding Structures 2/ | Total |
| | (dollars) | (dollars) | (dollars) |
| Crops and Pasture | 158 | 534 | 692 |
| Flood Plain Scour | 14 | 35 | 49 |
| Other Agricultural | 291 | 1,091 | 1,382 |
| Roads, Bridges, etc. | 68 | 252 | 320 |
| Indirect | 19 | 88 | 107 |

1/ Source of data: table 37, Appendix IV

2/ Not recommended at this time

Information by sample tributary areas and main stream reaches was combined to arrive at subwatershed evaluations. This is illustrated in table 53.

The benefits by subwatersheds were summed to obtain the total for the watershed (table 54).

## METHOD OF DETERMINING ANNUAL BENEFIT FROM INTENSIFIED USE OF THE FLOOD PLAIN

Flood control benefits are expected to result from more intensive agricultural use of bottomland areas which will be made possible by the reductions in extent and frequency of flooding resulting from the recommended floodwater retarding structures and channel improvement. Such areas are of two general types.

The flood plains of small tributaries immediately below floodwater retarding structures will receive a high degree of protection from flooding. Consequently a large percentage of such areas will become suited for more intensive use.

The second type of area which will become suited for more intensive use consists of portions of the flood plains along the larger tributaries. These portions include areas which are overflowed only by larger than average size floods.

Table 53 - Summary of Flood Control Benefits from Reduction of Damage, 1949 Prices, Clear Fork Subwatershed 1/
Brazos River Watershed

| Sample Area | Source of Benefit | Average Annual Benefit: From Land Treatment Measures (dollars) | From Floodwater Retarding Structures 3/ (dollars) | Total (dollars) |
|---|---|---|---|---|
| Mulberry Creek 2/ | Crop and Pasture | 1,461 | 4,922 | 6,383 |
| | Other Agricultural | 2,685 | 10,063 | 12,748 |
| | Scour | 125 | 322 | 447 |
| | Road, Bridge, Railroad | 589 | 2,198 | 2,787 |
| | Indirect | 172 | 809 | 981 |
| Main Stream Reaches (7-11) | Crop and Pasture | 1,721 | 2,277 | 3,998 |
| | Other Agricultural | 338 | 717 | 1,055 |
| | Scour | 6 | 10 | 16 |
| | Road, Bridge, Railroad | 58 | 112 | 170 |
| | Indirect | 227 | 607 | 834 |
| Main Stream Reaches (1-4) | Crop and Pasture | 3,615 | 2,769 | 6,384 |
| | Other Agricultural | 1,888 | 1,286 | 3,174 |
| | Scour | 52 | 37 | 89 |
| | Road, Bridge, Railroad | 417 | 107 | 524 |
| | Indirect | 465 | 380 | 845 |
| Subwatershed Total | Crop and Pasture | 6,797 | 9,968 | 16,765 |
| | Other Agricultural | 4,911 | 12,066 | 16,977 |
| | Scour | 183 | 369 | 552 |
| | Road, Bridge, Railroad | 1,064 | 2,417 | 3,481 |
| | Other Nonagricultural 4/ | 225 | 279 | 504 |
| | Valley Sediment 4/ | 59 | 161 | 220 |
| | Reservoir Sediment 4/ | 5,534 | 13,176 | 18,710 |
| | Water Treatment 4/ | 534 | 1,204 | 1,738 |
| | Indirect | 864 | 1,796 | 2,660 |
| | GRAND TOTAL | 20,171 | 41,436 | 61,607 |

1/ Source of data: Table 38, Appendix IV.
2/ Sample tributary used in the analysis.
3/ Floodwater retarding structures not recommended in this subwatershed at this time.
4/ Calculated on a subwatershed basis.

Table 54 - Average Annual Benefits Through Reduction of Damage, 1949 Prices, by Subwatersheds 1/
Brazos River Watershed

| Subwatershed | Average Annual Benefit from Reduction of Floodwater and Sediment Damage: From the Land Treatment Measures | From Floodwater Retarding Structures | From Channel Improvement | Total |
|---|---|---|---|---|
| | (dollars) | (dollars) | (dollars) | (dollars) |
| Salt Fork | 1,534 | 12,454 2/ | - | 13,988 |
| Brazos above Possum Kingdom | 14,241 | - | - | 14,241 |
| California Creek | 3,385 | - | - | 3,385 |
| Elm Creek | 2,144 | - | - | 2,144 |
| Hubbard Creek | 7,391 | 20,813 2/ | - | 28,204 |
| Clear Fork | 20,171 | 41,436 2/ | - | 61,607 |
| Possum Kingdom | 3,684 | 7,918 2/ | - | 11,602 |
| Possum Kingdom to Whitney | 38,392 | 30,746 3/ | - | 69,138 |
| Palo Pinto Creek | 5,022 | 19,739 2/ | - | 24,761 |
| Paluxy Creek | 26,590 | 46,529 3/ | - | 73,119 |
| Nolands River | 4,971 | - | - | 4,971 |
| Aquilla Creek | 49,367 | 58,902 | - | 108,269 |
| Whitney to Waco | 9,176 | 4,482 | - | 13,658 |
| Waco to Little River | 180,659 | 312,050 | 104,416 | 597,125 |
| Little Brazos | 234,124 | 382,012 | - | 616,136 |
| Navasota River above Dam | 53,265 | 59,595 | 57,779 | 170,639 |
| Yegua River above Dam | 12,306 | 20,383 | - | 32,689 |
| Mill Creek | 8,725 | 34,785 2/ | 4,739 2/ | 48,249 |
| Little River to Irrigation | 9,242 | 37,743 2/ | 7,078 2/ | 54,063 |
| Brazos River exclusive of Little and Bosque Rivers | 684,389 | 1,089,587 3/ | 174,012 3/ | 1,947,988 |
| Little River | 615,369 | 2,370,014 | 54,923 | 3,040,306 |
| Bosque River | 43,887 | 134,316 | - | 178,203 |
| Total - Brazos River Watershed | 1,343,645 | 3,593,917 3/ | 228,935 3/ | 5,166,497 |

1/ Source: Table 39, Appendix IV

2/ These independent measures not recommended at this time.

3/ Only a portion of these independent measures are recommended at this time.

Present floodplain land use was determined by detailed investigation of sample tributary areas. The location and extent of the areas which would become suitable for more intensive use following construction of the floodwater retarding structures was determined by:

1. Hydrologic analysis of the effect of the structures on frequency, depth and duration of flooding.

2. Study of soil conservation survey data to ascertain the suitability of protected lands for more intensive use.

The following assumptions were made concerning the increased intensity of land use to be expected on the protected areas:

1. Most of the present meadow and idle land would be used for cropland.

2. Land now used for small grain, but suited for alfalfa or clean-tilled crops generally would be so used.

3. Portions of the land now used for pasture would be converted to cropland. The portion so converted would depend upon the suitability of the land for crop use and upon the agricultural economy of the area.

4. The percentages of the new cropland used for various crops would be approximately the same as for present cropland.

5. The area on which intensification was calculated was confined to the portion of the flood plain at elevations above those flooded on an average of once in two or three years after installation of the recommended program.

In the calculation of benefits, the average annual gross value of the production in the area protected was determined both for present land use and for future conditions (it was assumed that no changes would occur in the per-acre yields). Costs of production based on Experiment Station data including all machinery expense, labor (whether performed by the operator and his family or hired labor) and an added charge for taxes and overhead, were deducted from the gross return to give a net increase in value of production. The expected annual damage to the increased production from the floods remaining after installation of the recommended program was deducted from the net income to arrive at the net benefit. This was multiplied by the appropriate conversion factor for the area to determine the benefit under predicted normal levels. Table 55 illustrates the procedure for the Mulberry Creek sample tributary flood plain. Table 56 shows average annual benefit from this source by subwatersheds under 1949 and predicted normal prices.

Table 55 - Increased Annual Income Through More Intensive Use of Protected Flood Plain (1948 Prices)
Mulberry Creek Sample Tributary

Brazos River Watershed

| Item | Acres | Gross Value of Production (dollars) | Costs (dollars) | Net Return (dollars) | Net Increase in Income (dollars) |
|---|---|---|---|---|---|
| Present Land Use | | | | | |
| Cotton | 47 | 3,628 | 1,850 | | |
| Wheat | 196 | 5,020 | 2,391 | | |
| Sorghum | 94 | 2,171 | 1,180 | | |
| Meadow | 7 | 249 | 106 | | |
| Pasture | 3,009 | 18,235 | 2,257 | | |
| Woods | 344 | - | - | | |
| Taxes and Overhead 1/ | (337) | - | 842 | | |
| Total | 3,697 | 29,303 | 8,626 | 20,677 | |
| Future Land Use | | | | | |
| Cotton | 81 | 6,252 | 3,188 | | |
| Wheat | 337 | 8,631 | 4,111 | | |
| Sorghum | 162 | 3,740 | 2,033 | | |
| Meadow | - | - | - | | |
| Pasture | 2,773 | 16,804 | 2,080 | | |
| Woods | 344 | - | - | | |
| Taxes and Overhead 1/ | (580) | - | 1,450 | | |
| Total | 3,697 | 35,427 | 12,862 | 22,565 | 1,888 |
| Flood Damage on Added Production | | | | | 103 |
| Net Annual Benefit | | | | | 1,785 2/ |

1/ Taxes and overhead are calculated at $2.50 per acre on cultivated land only.
2/ Assuming floodwater retarding structures installed. Because these structures are not justified at this time in Mulberry Creek Sample, the reductions in flooding obtained without them would be insufficient to allow changes in land use and this benefit is not included in the evaluation of the recommended program.

Table 56 - Benefit Through More Intensive Use of Flood Plain Lands Resulting From the Recommended Program

Brazos River Watershed

| Subwatershed | Benefit under 1949 Prices | | | Benefit under "Normal" Prices | | |
|---|---|---|---|---|---|---|
| | From Floodwater Retarding Structures (dollars) | From Channel Improvement (dollars) | Total (dollars) | From Floodwater Retarding Structures (dollars) | From Channel Improvement (dollars) | Total (dollars) |
| Possum Kingdom to Whitney | 11,180 | - | 11,180 | 7,192 | - | 7,192 |
| Paluxy Creek | 14,008 | - | 14,008 | 8,898 | - | 8,898 |
| Aquilla Creek | 41,374 | - | 41,374 | 25,671 | - | 25,671 |
| Whitney to Waco | 3,359 | - | 3,359 | 2,057 | - | 2,057 |
| Waco to Little River | 94,995 | 82,588 | 177,583 | 59,026 | 51,354 | 110,380 |
| Little Brazos | 21,945 | - | 21,945 | 13,519 | - | 13,519 |
| Navasota River above Dam | 30,229 | 13,655 | 43,884 | 18,515 | 8,389 | 26,904 |
| Yegua Creek above Dam | 14,994 | - | 14,994 | 9,226 | - | 9,226 |
| Brazos River exclusive of Little and Bosque Rivers | 232,084 | 96,243 | 328,327 | 144,104 | 59,743 | 203,847 |
| Little River | 332,950 | - | 332,950 | 219,046 | - | 219,046 |
| Bosque River | 63,065 | - | 63,065 | 39,951 | - | 39,951 |
| Total Brazos River Watershed | 628,099 | 96,243 | 724,342 | 403,101 | 59,743 | 462,844 |

# METHOD OF DETERMINING CONSERVATION BENEFITS

The land treatment measures of the recommended program will be applied to the agricultural land in the Brazos River Watershed. As 25,813,000 acres out of a total 26,988,000 acres in the watershed, or about 96 percent of the total area, are operated under a farm or ranch economy it is essential that consideration be given to the effect that the program will have on agricultural income. A comparison of the crop and livestock production and agricultural income for each conservation problem area was made for the future with the recommended program and for the future without treatment to facilitate the evaluation of the effects of the program.

The differences in income and expense revealed by this analysis, plus the cost of installation and maintenance of the measures, serve as the basis for determining conservation benefit and cost of the recommended flood control program. In any conservation problem area an increase in gross income or a reduction in expense with treatment over such income or expense without treatment was regarded as a benefit. If application of the remedial program resulted in reduced gross income or increased expenses, the item was classed as a cost.

## Effect of the Remedial Program on Crop and Pasture Yields

In estimating the conservation benefit and cost of the program upon agriculture it was necessary to determine the effect of the measures upon crop and pasture yields.

Crop Yields: Reduction in Cotton acreage, improved seed, mechanization and increasing emphasis upon soil improving practices have obscured the normal trends of crop yield caused by continuous cropping. The forced selection of high-yielding land for cotton production and the use of the lower-yielding acres for feed production, or their retirement from crop use, has so affected the average yields that the usual methods of analysis of yield trends give a distorted view of actual conditions.

Present Yields and Future Yields Without Land Treatment Measures: The present crop yields, as determined through investigations during the survey of the Little River Watershed, were applied to the same conservation problem areas throughout the Brazos River Watershed. Yields in the conservation problem areas not represented in the Little River Watershed were estimated from data 1/ supplied by agricultural field technicians and other qualified agricultural workers.

To determine the effect of continued crop production under present cultural practices, the results of the soil decline study made by the Soil Conservation Service were used. Capability classes are closely

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1/ Effects of Soil Conservation Practices on Production, Region IV; Soil Conservation Service, U. S. D. A., Fort Worth, Texas

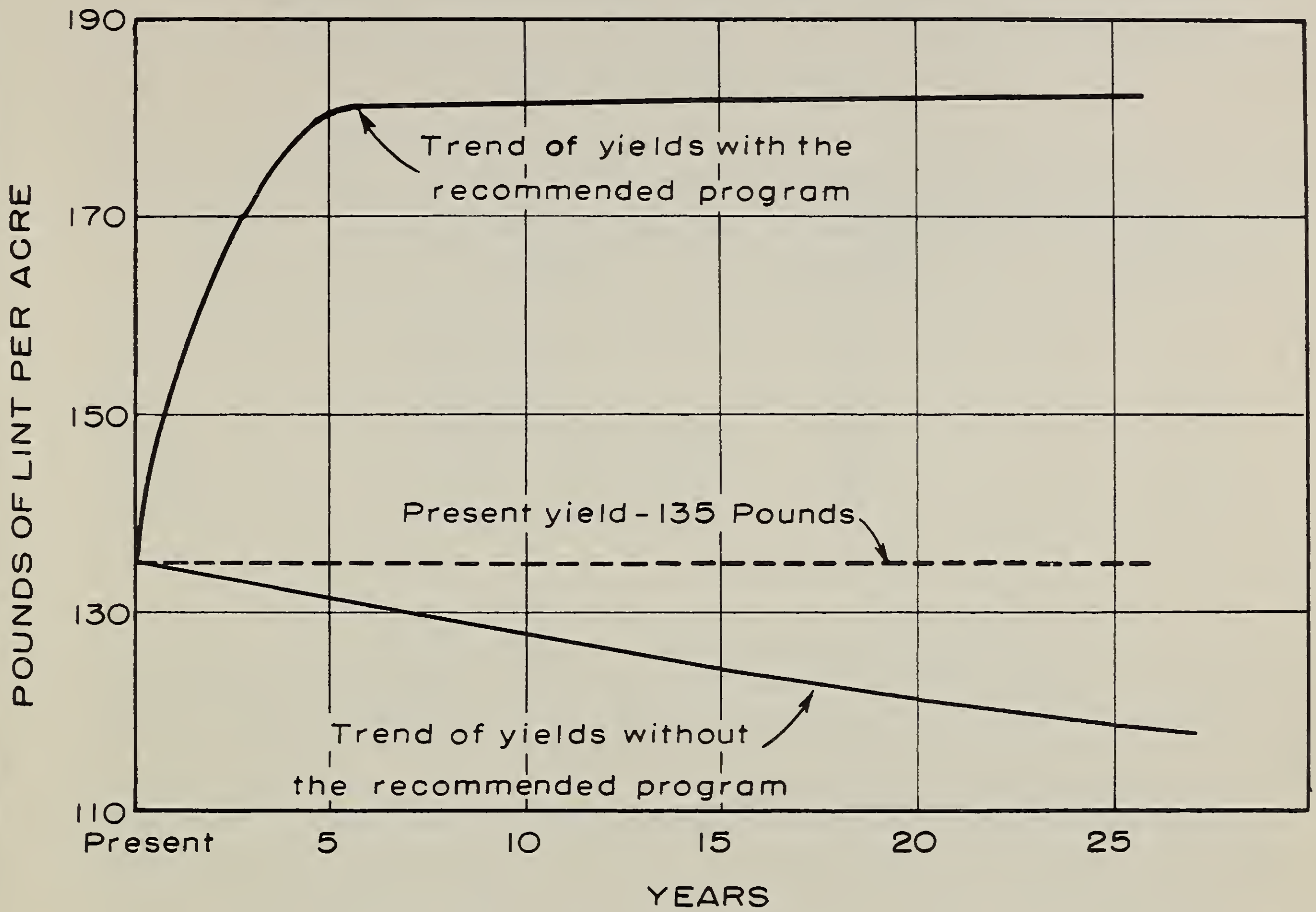
related to the crop producing ability of the remaining soil. It was assumed that productivity would decline at the rate at which soil losses were occurring since this loss is a measure of the reduction in the average capability of the land for crop production.

For example, in the Blackland Prairie conservation problem area, the present average depth of soil on cultivated lands is 11.97 inches. It has been determined that this soil (which has, at present, an average capability of about Class III, or is suitable for cultivated crops if complex or intensive measures are applied) will be reduced one capability class in 37 years. During this period (37 years), 3.50 inches of soil would be lost and productivity would then be such that the land would be retired to grass or used for hay crops. Assuming that productivity, at least for cultivated crops, would be completely destroyed when the 11.97 inches of soil is removed, the trend in reduction of yields in the future will be somewhat faster than the rate of soil loss. It will approximate that rate, however, for the period before the soil becomes too poor for the economical production of the present crops.

Yield trends in the future without remedial measures were calculated using the present yields as a starting point. It was assumed that yields would remain constant after 15 years. This resulted in a conservative estimate and did not require the exact adjustment of the lower portion of the yield trend curve for the future without remedial measures (to reflect the economic factors of forced changes in crops or cultural practices). The trend of future cotton yield which can be expected under the present crop producing methods and practices of the Blackland Prairie without remedial treatment is shown in figure 31.

Future Yields with Land Treatment Measures: All available evidence on the effect of land treatment upon yields was related to similar conditions within the watershed. Several hundred historical yield records covering about 360,000 acres in farm units in soil conservation districts upon which conservation measures had been applied were used. These records cover a period of from 2 to 6 years and are an indication of the effects that can be expected from the application of land treatment measures. It was recognized that these records may have included some increases due to superior management on those farms where conservation practices had been adopted, consequently the increases shown were adjusted in all cases where they seemed unusually high. Examples of such adjustments are shown in table 57.

It was believed that these adjustments offset most of the bias that may have accompanied better management on the conservation farms. A study made by the Texas Agricultural Experiment Station reports that yield increases from contour cultivation and terracing in the Rolling Red Plains ranged from 7 to 50 percent, depending on the crop and the




ROLLING RED PLAINS
CONSERVATION PROBLEM AREA

Fig. 31

COTTON YIELD TRENDS IN THE FUTURE
WITH AND WITHOUT THE RECOMMENDED PROGRAM
BRAZOS RIVER WATERSHED-TEXAS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT - CHIEF
REGION 4 CONSERVATOR – LOUIS P. MERRILL
REFERENCE -- SOIL DECLINE AND LAND DRAINAGE RECORDS, SOIL CONSERVATION SERVICE.

| CARTOGRAPHIC APPROVAL | | TECHNICAL APPROVAL | |
|---|---|---|---|
| C.B. Eason | | A.H. Bean | |
| COMPILED | TRACED | CHECKED | DATE |
| A.H.B. | E.A.T. | A.H.B. | 4-13-49 |

4-L-7245-6

Table 57 - Comparison of Increases in Yields of Selected Crops as a Result of Conservation Farming, as Shown by Records, With Increases Used in Evaluation of the Recommended Program

Brazos River Watershed

| Crop | Conservation Problem Area | Percentage Increase in Yields: Shown by Records | Percentage Increase in Yields: Used in Evaluation |
|---|---|---|---|
| Cotton | Blackland | 29 | 21 |
| Oats | Blackland | 19 | 0 |
| Hay | Blackland | 40 | 13 |
| Wheat | Rolling Red Plains | 34 | 0 |
| Sorghum | Rolling Red Plains | 61 | 10.5 |
| Cotton | Rolling Red Plains | 35 | 35 |

practice. 1/ Another study conducted by the University of Illinois Agricultural Experiment Station in cooperation with the Soil Conservation Service compared the average advantage in Illinois (during a 7 year period) of contouring against cultivation up and down the slopes on the same farm. 2/ In this study the effect of differences in management, equipment and soils were eliminated to a great extent. The advantage in yield due to contour cultivation alone was reported to be 12 percent for corn, 16 percent for oats and 17 percent for wheat. As these increases were obtained as a result of contour cultivation only, it was considered that the yield increases shown in table 58 and used in this report were conservative and reasonable.

The percentage of increase shown by these records can be expected within a period of about 5 years. By the fifth year after application most land treatment measures should have reached their maximum effectiveness. By applying the percentages of increase to present yields, the expected yields after treatment were calculated. Table 58 shows the present and future yields for some of the major crops.

Pasture Yields: The present safe stocking rates, or the surface acre requirements per animal unit, were obtained from range surveys

1/ Czarowitc, P. H. and Bonnen, C. A., "Information Basic to Farm Adjustments in the Rolling Plains Area of Texas", Bulletin 617 Texas Agricultural Experiment Station, September 1942.

2/ Sauer, E. L., "Methods of Evaluating Soil Conservation Measures," page 655, Journal of Farm Economics, February 1949.

Table 58 - Estimated Crop and Pasture Yields Per Acre at Present and Future Yields With and Without the Recommended Program 1/

Brazos River Watershed

| Crop | Unit | Coastal Prairie 2/ | | | Forested Coastal Plain | | | Cross Timbers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Present | Future | | Present | Future | | Present | Future | |
| | | | Treated | Untreated | | Treated | Untreated | | Treated | Untreated |
| Cotton | Lb. Lint | 200 | 220 | 198 | 135 | 203 | 126 | 80 | 103 | 76 |
| Corn | Bu. | 25 | 28 | 25 | 17 | 17 | 16 | 18 | 23 | 17 |
| Wheat | Bu. | - | - | - | - | - | - | 10 | 10 | 9.5 |
| Oats | Bu. | 40 | 41 | 39.5 | 30 | 31 | 28 | 25 | 31 | 24 |
| Sorghum | Lbs. Fodder | 4,400 | 4,840 | 4,356 | 2,500 | 2,550 | 2,325 | 2,500 | 3,050 | 2,370 |
| Peanuts | Lbs. | 600 | 630 | 594 | 530 | 541 | 493 | 530 | 790 | 505 |
| Truck | Percent | 100 | 100 | 99 | 100 | 100 | 93 | 100 | 100 | 91 |
| Rice | Bu. | 56 | 56 | - | - | - | - | - | - | - |
| Pasture | Ac/A.U. | 7 | 5 | 7 | 6 | 5.7 | 6 | 24 | 16 | 26 |
| | | Rolling Red Plains | | | Blackland Prairie | | | Grand Prairie | | |
| Cotton | Lb. Lint | 135 | 182 | 124 | 155 | 188 | 137 | 135 | 174 | 123 |
| Corn | Bu. | 20 | 21 | 18 | 26 | 36 | 23 | 23 | 29 | 21 |
| Wheat | Bu. | 10 | 10 | 9 | 10 | 12 | 9 | 10 | 10 | 9 |
| Oats | Bu. | 40 | 41 | 37 | 39 | 39 | 34 | 40 | 48 | 37 |
| Sorghum | Lb. Fodder | 3,000 | 3,315 | 2,760 | 3,000 | 3,390 | 2,840 | 3,000 | 3,000 | 2,750 |
| Pasture | Ac/A. U. | 56 | 36 | 56 | 6 | 5 | 6 | 20 | 15 | 21 |
| | | Reddish Prairie | | | High Plains | | | Edwards Plateau 3/ | | |
| Cotton | Lb. Lint | 135 | 182 | 124 | 200 | 252 | 184 | | | |
| Corn | Bu. | 20 | 21 | 18 | - | - | - | | | |
| Wheat | Bu. | 10 | 10 | 9 | 10 | 10 | 9 | | | |
| Oats | Bu. | 35 | 36 | 32 | - | - | - | | | |
| Sorghum | Lbs. Fodder | 3,000 | 3,315 | 2,760 | 3,000 | 3,255 | 2,760 | | | |
| Pasture | Ac/A. U. | 38 | 26 | 38 | 42 | 24 | 42 | 51 | 36 | 51 |

1/ Source: Brazos Flood Control Survey.

2/ Where increases are calculated on Bottomland for conservation benefits, use same percentage increase as Coastal Prairie.

3/ Information inadequate for Edwards Plateau. Yields are similar to Reddish Prairie.

made in comparable areas within the Little River Watershed. 1/ These surveys were made within conservation problem areas which extend through other portions of the Brazos River Watershed. Within each of these conservation problem areas, field checks show that there is little measurable difference in cover types, composition and vigor of the vegetation and in grazing utilization between the portions of the Brazos River Watershed inside the Little River subwatershed and those outside.

In Appendix I a description of the various cover types shows that a relatively small proportion of the grassland is in what might be termed an "excellent" condition or is producing to its maximum.

As the evaluation of the effects of the recommended remedial program was carried through a budgetary analysis by conservation problem areas, a present average grazing capacity or safe stocking rate for each was developed. This capacity represents the conclusions drawn from the range survey, the estimates of range specialists, and such information as is available from technical personnel in the field.

During the investigations for the Trinity River flood control survey, a study was made of grassland by conservation problem areas. 2/ Trends of future production, both with and without the application of the recommended program, were developed. The conclusions of this investigation were applied to the following similar areas in the Brazos River Watershed: Forested Coastal Plain, Blackland Prairie, Cross Timbers, and Grand Prairie.

In order to secure comparable information for the remaining conservation problem areas in the Brazos River Watershed (High Plains, Rolling Red Plains, Reddish Prairie, Edwards Plateau and Coast Prairie) information was secured from the range specialists and field technicians in these areas. Twenty-four field estimates were secured which covered the following points:

(1) The various range sites in each conservation problem area.

(2) The percentage of each range site which is now classified into each of the four condition classes (excellent, good, fair, poor).

(3) The recommended safe stocking rates for each condition class in each range site.

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1/ Interim Survey Report, Brazos River and Tributaries, Texas, Little River Watershed, Department of Agriculture, 1950.

2/ Trinity River Flood Control Survey Report, Appendix 6, 1939 unpublished, U. S. Department of Agriculture.

(4) The percentage of each range site which would be classified into each condition class after application of the recommended program and a short period of recovery.

The information was weighted by: (1) the area of conservation problem area within the district with which the range technician was familiar; and (2) by the actual distribution of range sites, which was secured by analysis of conservation survey tabulations. These calculations resulted in the recommended stocking rates at present and with the recommended program, for the conservation problem areas listed above. Since range deterioration is very slow, under present conditions of use, a conservative figure (present conditions) was used in most cases for the expected safe grazing capacity in the future without the recommended program. Table 59 shows the recommended safe stocking rates at present and table 60 shows the effects of the recommended program. The decrease in surface acres needed to carry an animal unit for a year without harm to the grass cover is a measure of the benefit.

## Agricultural Income

The land treatment costs and benefits in portions of the Brazos River Watershed included in the Little River and Bosque River subwatersheds were analyzed in previous reports through calculation of operating budgets on representative sizes and types of farms.

During the 10-year period between the Census of 1935 to that of 1945, the average size of farm in Texas increased by 34 percent, and the acreage of cropland harvested per farm increased by 40 percent. In 1935, almost 73 percent of all farms in Texas reported cotton but the percentage had fallen to 45 in 1945. These and other changes in farm size and organization were so profound that it was decided that the impact of the recommended program upon the agricultural economy of the watershed could be determined as well by considering the permanent conservation problem area as a unit as by analyzing the effect upon transitory sizes and types of farms. An additional factor was the not inconsiderable expenditure of funds that would be necessary to insure an adequate field investigation of farm and ranch sizes and types. Therefore, the conservation problem area was the evaluation unit in all areas of the Brazos River Watershed outside the Little River and Bosque River subwatersheds.

Determination of Crop and Livestock Organization: Counties and other civil divisions lying wholly or almost entirely within a conservation problem area were used as the sampling units. Census data covering cropland and livestock organization were totaled for all the sample units in each conservation problem area. From these totals, the percentage of cropland in each crop, the number of livestock per acre

Table 59 - Recommended Stocking Rates by Range Sites and Condition Classes, at Present

Brazos River Watershed

| Range Site | Recommended Stocking Rates | | | |
|---|---|---|---|---|
| | Excellent (Ac/AU) 1/ | Good (Ac/AU) | Fair (Ac/AU) | Poor (Ac/AU) |
| Cross Timbers | | | | |
| Bottomland | 10 | 12 | 17 | 23 |
| Typical upland | 13 | 16 | 24 | 32 |
| Grand Prairie | | | | |
| Bottomland | 8 | 10 | 14 | 22 |
| Ordinary upland | 12 | 15 | 22 | 30 |
| Steep slopes & ridges | 16 | 20 | 28 | 40 |
| High Plains | | | | |
| Upland | 18 | 25 | 35 | 55 |
| Shallow | 29 | 38 | 59 | 95 |
| Mixed land | 15 | 20 | 30 | 60 |
| Sand hills | 25 | 33 | 50 | 100 |
| Poorly drained | 15 | 20 | 30 | 60 |
| Rolling Red Plains | | | | |
| Bottomlands | 11 | 15 | 24 | 40 |
| Normal upland | 18 | 24 | 37 | 62 |
| Hill & ridges | 24 | 33 | 50 | 79 |
| Shinnery | 25 | 32 | 49 | 76 |
| Rough broken | 34 | 48 | 72 | 200 |
| Edwards Plateau | | | | |
| Bottomlands | 13 | 17 | 25 | 42 |
| Normal upland | 17 | 25 | 36 | 56 |
| Hills & ridges | 20 | 27 | 41 | 68 |
| Rough broken | 25 | 35 | 60 | 62 |
| Reddish Prairies | | | | |
| Bottomlands | 14 | 22 | 29 | 43 |
| Normal upland | 16 | 22 | 31 | 48 |
| Hills & ridges | 22 | 30 | 40 | 60 |
| Post Oak hills | 30 | 39 | 59 | 74 |
| Deep sands | 16 | 23 | 32 | 53 |
| Coast Prairie | | | | |
| Bottomland | 10 | 12 | 15 | 15 |
| Fertile Blackland | 4 | 5 | 7 | 8 |
| Sandy prairie | 5 | 6 | 8 | 10 |
| Hardpan flats | 5 | 6 | 8 | 10 |

1/ Acres per animal unit, year long.

Table 60. Recommended Stocking Rates both with and without the Recommended Program

Brazos River Watershed

| Conservation Problem Area | Present Safe Stocking Rates | Future Safe Stocking Rate: With Recommended Program | Future Safe Stocking Rate: Without Recommended Program |
|---|---|---|---|
| | (AC/AU) 1/ | (Ac/AU) | (Ac/AU) |
| High Plains | 42 | 24 | 42 |
| Rolling Red Plains, western section | 61 | 38 | 61 |
| Rolling Red Plains, central area | 51 | 33 | 51 |
| Edwards Plateau | 51 | 36 | 51 |
| Reddish Prairie | 38 | 26 | 38 |
| Cross Timbers | 24 | 16 | 26 |
| Grand Prairie | 20 | 15 | 21 |
| Blackland Prairie | 6 | 5 | 6 |
| Forested Coastal Plain | 6 | 5.7 | 6 |
| Coast Prairie | 7 | 5 | 7 |

1/ Acres per animal unit, year long.

of pasture or cropland, and the distribution of the total number of livestock among the various species were calculated for each conservation problem area.

Calculation of Changes in Agricultural Income: The following information was used to calculate the changes in agricultural income for each conservation problem area:

1. Per-unit production for the various crop and livestock enterprises in each area.

2. Such expenses of production, including overhead as well as per-unit production costs, as would be affected by the recommended program.

3. The sale, or use as feed, of commodities produced.

4. Current (1948) prices for products sold (table 61).

Table 61 - Farm Prices, 1948 1/

Brazos River Watershed

| Item | Unit | Price |
|---|---|---|
| | | (dollars) |
| Corn | Bu. | 1.76 |
| Wheat | Bu. | 1.97 |
| Oats | Bu. | 0.89 |
| Sorghum (grain) | Cwt. | 1.95 |
| Hay, all, loose | Ton | 17.80 |
| Cotton | Lb. | 0.3711 2/ |
| Peanuts | Lb. | 0.104 |
| Rice | Bu. | 2.65 |
| Beef Cattle | Cwt. | 22.60 |
| Veal calves | Cwt. | 25.50 |
| Sheep | Cwt. | 11.20 |
| Lambs | Cwt. | 22.00 |
| Milch cows | Per head | 145.00 |
| Butterfat | Lb. | 0.70 |
| Wool | Lb. | 0.49 |

1/ Division of Agricultural Statistics, B.A.E., U.S. Department of Agriculture, Austin, Texas, August 1948. Based on State of Texas data with adjustments made on calendar year basis.

2/ Includes seed.

Data from the following sources served as the basis for the above factors:

1. The census of 1940 and the census of agriculture of 1945.

2. Publications of various state and Federal agencies pertinent to the survey area.

3. Information and records of soil conservation districts, work units and field technical personnel.

4. County records of the Production and Marketing Administration.

5. Field schedules taken from farms and ranches in the Little River subwatershed.

## Calculation of the Effects of the Program on Agricultural Production and Income

Without Program: The future cropland use and livestock organization in each conservation problem area, with and without treatment, are necessary for budgetary analysis. Therefore, the present cropland use and livestock organization were adjusted for the future, with and without treatment. The land use and the number of livestock in each species in the future without treatment were assumed to remain the same as at present. However, any changes in crop and pasture yields expected in the future without treatment were taken into consideration. In most cases, crop and pasture yields are expected to decline in the future without treatment and this was reflected in the quantity of cash crops to be sold and of feed expected to be purchased or sold in the future.

With Program: In the future, with treatment, the land use was changed by converting cropland or idle land to pasture wherever recommended. Where changes were necessary and the quantity of idle cropland was insufficient to meet the shift, the converted acres were deducted from the different crops as shown at present, on the basis of the percentage that each crop occupied of the total cropland. Any changes in crop yields expected to result from the program were applied to the adjusted cropland acres.

Livestock numbers in the future, with treatment, were determined by dividing the surface acre safe stocking rates or grazing capacity (table 60) into the total pasture acres. This gave the number of animal units to be carried on permanent pasture. To the number of livestock thus maintained those carried on supplemental feed and tame pasture were added. The increase in number was prorated among cattle, sheep and goats on the basis of their present number in each conservation problem area.

Changes in Income: The major steps in the process of calculating changes in income in the future, with and without the recommended program, were as follows:

1. Crop yields were applied to the acreage in the various crops to ascertain the total units produced.

2. Livestock production per unit was applied to livestock numbers to get total production.

3. Current prices were applied to all products, exclusive of feed fed to livestock, where there was a change in the quantity produced.

4. Production expense factors were applied to each product where there was a change in the quantity produced, in overhead costs, or in the expense of production.

5. The changes in income and expenses were summarized for each enterprise to obtain the gross and net changes in income and expense.

## Annual Installation and Maintenance Costs of the Recommended Program

Installation costs occasioned by the recommended program were calculated for each conservation problem area and were converted to an annual basis by multiplying by an interest rate of four percent. Maintenance costs of the treatment measures were calculated on an annual basis due to the fact that such costs are recurrable annually.

## Determination of Conservation Benefits and Costs

Annual conservation benefits and costs were determined by summarizing the differences in gross income and expense, with and without the remedial program, for each conservation problem area (table 62). In this calculation a loss in gross income or an increased expense was classed as a cost, whereas a gain in gross income or a decreased expense was considered a benefit. It was assumed in these calculations that 100 percent of the farmland would be included in the participating acreage. 1/ Benefits and costs at 1948 prices were multiplied by appropriate factors to convert them to 1949 prices.

## Effect on Total Agricultural Production

The changes in agricultural production in the Brazos River Watershed as a result of land use changes and the installation of the recommended program upon all of the watershed agricultural lands were estimated (table 63). It can be seen that these increases are moderate. They

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1/ The land included within floodwater retarding structures is included in this evaluation since evaluation of these structures and actual determination of their numbers is the final step in the survey. The subtraction of the benefits and costs from watershed totals would have had no effect on total benefit-cost ratios and only a small effect on the total program costs. Revision of all tables was not considered advisable.

Table 62 - Average Annual Costs (Land Owner and Operator) and Conservation Benefits from the Land Treatment Program by Conservation Problem Area, 1949 Prices

Brazos River Watershed

| Conservation Problem Area | Annual Benefits | Installation | Maintenance | Installation and Maintenance | Operating Costs | Total: All Costs |
|---|---|---|---|---|---|---|
| Brazos River Watershed Exclusive of Little River and Bosque River Subwatersheds | | | | | | |
| Forested Coastal Plain | 2,502,755 | 170,452 | 299,154 | 469,606 | 1,873,609 | 2,343,215 |
| Blackland Prairie | 7,153,756 | 196,719 | 447,499 | 644,218 | 1,511,191 | 2,155,409 |
| East Cross Timbers | 191,321 | 14,491 | 25,438 | 39,929 | 59,890 | 99,819 |
| West Cross Timbers | 1,066,652 | 77,489 | 84,733 | 162,222 | 94,801 | 257,023 |
| Grand Prairie | 1,227,045 | 62,902 | 101,835 | 164,737 | 211,887 | 376,624 |
| Reddish Prairie | 1,297,206 | 128,944 | 213,070 | 342,014 | 868,059 | 1,210,073 |
| Edwards Plateau | 321,605 | 51,079 | - | 51,079 | 111,636 | 162,715 |
| Rolling Red Plains | 709,704 | 40,744 | 17,111 | 57,855 | 188,738 | 246,593 |
| Subtotal | 14,470,004 | 742,820 | 1,188,840 | 1,931,660 | 4,919,811 | 6,851,471 |
| Little River Subwatershed | 9,463,050 | 306,842 | 545,911 | 852,753 | 2,302,574 | 3,155,327 |
| Bosque River Subwatershed | 1,412,403 | 63,274 | 78,030 | 141,304 | 322,122 | 463,426 |
| Total, Brazos River Watershed | 25,345,497 | 1,112,936 | 1,812,781 | 2,925,717 | 7,544,507 | 10,470,224 1/ |

1/ This total cost, $10,470,224, differs slightly from the cost shown in Table 1, $10,451,732, because of rounding of costs per unit to nearest whole dollars.

Table 63 - Estimated Changes in Production of Selected Products as a Result of the Recommended Program, Expressed as a Percentage of the Present (1948) Production.

Brazos River Watershed

| Product | Present Production | Future Production With Program |
|---|---|---|
| | (Percent) | (Percent) |
| Corn | 100 | 106 |
| Wheat | 100 | 84 |
| Cotton | 100 | 120 |
| Oats | 100 | 91 |
| Peanuts | 100 | 96 |
| Sorghum | 100 | 95 |
| Beef | 100 | 122 |
| Milk | 100 | 123 |
| Wool | 100 | 119 |

compare with estimated needs for farm output of approximately 110.9 under high employment and 107.0 under intermediate employment in the period 1955-65 1/, using 1947 as 100. Furthermore, the estimated increases resulting from the recommended program are greater for livestock products, in line with recent trends in consumption and the expectations of most authorities regarding the future demands for food and fiber. Black and Kiefer 2/ estimate the need by 1960 under conditions of moderate unemployment as increases of 3 percent for cereals, 45 percent for meat and 30 percent for milk over food consumption in the period 1935 to 1939. Such changes as might be incicated by price relationships could be made without altering the fundamentals of the recommended program. In all probability, the changes in production estimated in table 63 would have little effect on nationwide price relationships.

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1/ Estimated in Table 4 "Long-Range Agricultural Policy. A Study of Selected Trends and Factors Relating to the Long-Range Prospect for American Agriculture", Committee on Agriculture, House of Representatives, Eightieth Congress, U.S. Government Printing Office, March 1948. This report is probably conservative as it envisioned a population in 1950 about 3 million below the figure that apparently will be shown by the 1950 census.

2/ Black, John D. and Kiefer, Maxine E., Table 13, "Future Food and Agriculture Policy", McGraw - Hill, 1948.

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